2009

Water and Nutrient Research: In-field and Offsite Strategies—2008 Annual Report

Matthew J. Helmers
Iowa State University, mhelmers@iastate.edu

William G. Crumpton
Iowa State University, crumpton@iastate.edu

Peter Lawlor
Iowa State University

Carl H. Pederson
Iowa State University, carl@iastate.edu

Greg A. Stenback
Iowa State University, gastenba@iastate.edu

See next page for additional authors

Water and Nutrient Research: In-field and Offsite Strategies—2008 Annual Report

Abstract

Much of Iowa is characterized by relatively flat, poorly-drained soils which, with extensive artificial subsurface drainage, have became some of the most valuable, productive lands in the State. In 2002, the average land value for the 22-county area making up most of the Des Moines Lobe was $2,436 an acre, and 80.5% of that area was in row-crops (42.9% in corn and 37.6% soybeans). However, this drained land has also become a source of significant NO3 loss because of the changes in land-use and hydrology brought about by tile drainage. While surface runoff is decreased with subsurface drainage (resulting in decreased losses of sediment, ammoniumnitrogen, phosphorus, pesticides and micro-organisms), subsurface flow and leaching losses of NO3 are increased. This is due mostly to an increase in volume and the "short-circuiting" of subsurface flow, but also in part to the increased aeration of organic-rich soils with potentially increased mineralization and formation of NO3 (and less denitrification) in the soil profile.

The problem of excess nutrient loads can probably be ameliorated by a combination of in field and off site practices, but the limitations and appropriateness of alternative practices must be understood and outcomes must be measurable. Promising in field practices include nutrient management, drainage management, and alternative cropping systems. Nitrate-removal wetlands are a proven edge-of-field practice for reducing nitrate loads to downstream water bodies and are a particularly promising approach in tile drained landscapes. Strategies are needed that can achieve measurable and predictable reductions in the export of nutrients from tile drained landscapes. The principal objectives of this project are (1) to evaluate the performance of nutrient management, drainage management, and alternative cropping systems with respect to profitability and export of water and nutrients (nitrate-nitrogen and total phosphorus) from tile drained systems and (2) to evaluate the performance of nitrate-removal wetlands in reducing nitrate export from tile drained systems.

This annual report describes activities related to objectives 1 and 2 along with outreach activities that were directly related to this project. For objective 1, crop years 2005, 2006, and 2007 are presented. Also, outreach activities are noted for 2005, 2006, and 2007 to provide an overall project summary.

Disciplines

Agriculture | Bioresource and Agricultural Engineering

Authors

Matthew J. Helmers, William G. Crumpton, Peter Lawlor, Carl H. Pederson, Greg A. Stenback, Reid Christianson, and David Green

Matthew Helmers
William Crumpton
Peter Lawlor
Carl Pederson
Greg Stenback
Reid Christianson
David Green

Annual Report for Crop Year 2008
(January 1, 2005 – December 31, 2008)

Water and Nutrient Research: In-field and Offsite Strategies

Submitted to:
Iowa Department of Agriculture and
Land Stewardship

Submitted by:
Department of Agricultural and Biosystems Engineering
Department of Ecology, Evolution and Organismal Biology
Iowa State University, Ames

NUTRIENT AND WATER MANAGEMENT PROJECT 2005-2009

Much of Iowa is characterized by relatively flat, poorly-drained soils which, with extensive artificial subsurface drainage, have became some of the most valuable, productive lands in the State. In 2002, the average land value for the 22-county area making up most of the Des Moines Lobe was $2,436 an acre, and 80.5% of that area was in row-crops (42.9% in corn and 37.6% soybeans). However, this drained land has also become a source of significant NO_3 loss because of the changes in land-use and hydrology brought about by tile drainage. While surface runoff is decreased with subsurface drainage (resulting in decreased losses of sediment, ammonium-nitrogen, phosphorus, pesticides and micro-organisms), subsurface flow and leaching losses of NO_3 are increased. This is due mostly to an increase in volume and the "short-circuiting" of subsurface flow, but also in part to the increased aeration of organic-rich soils with potentially increased mineralization and formation of NO_3 (and less denitrification) in the soil profile.

The problem of excess nutrient loads can probably be ameliorated by a combination of in field and off site practices, but the limitations and appropriateness of alternative practices must be understood and outcomes must be measurable. Promising in field practices include nutrient management, drainage management, and alternative cropping systems. Nitrate-removal wetlands are a proven edge-of-field practice for reducing nitrate loads to downstream water bodies and are a particularly promising approach in tile drained landscapes. Strategies are needed that can achieve measurable and predictable reductions in the export of nutrients from tile drained landscapes. The principal objectives of this project are (1) to evaluate the performance of nutrient management, drainage management, and alternative cropping systems with respect to profitability and export of water and nutrients (nitrate-nitrogen and total phosphorus) from tile drained systems and (2) to evaluate the performance of nitrate-removal wetlands in reducing nitrate export from tile drained systems.

This annual report describes activities related to objectives 1 and 2 along with outreach activities that were directly related to this project. For objective 1, crop years 2005, 2006, and 2007 are presented. Also, outreach activities are noted for 2005, 2006, and 2007 to provide an overall project summary.

Gilmore City Project Site

Treatments

The specific treatments investigated at the Gilmore City Research Facility (GCRF) are listed in Table 1. All treatments except the harvestable perennials consist of eight plots with four in soybeans and four in corn each year. The harvestable perennials each have four plots. The harvestable perennials were investigated during the winter of 2004 and planted in spring 2005 after discussion with the investigators and IDALS personnel.

The treatments included allow for varied comparisons as follows:

- Timing of nitrogen application (treatments 1,2 and 3,4 vs. 5,6 and 7,8)
- Rate of nitrogen application (treatments 1,2 vs. 3,4 and 5,6 vs. 7,8 vs. 9,10)
- Method of nitrogen application (treatments 7,8 vs. 15,16)
- Potential impacts of tillage (treatments 7,8 vs. 11,12)
- Cropping practices through the use of a winter cover crop (treatments 7,8 vs. 13,14)

- Impacts of complete conversion to perennial vegetation (treatments 17 and 18 vs. other treatments)

Table 1. Treatments at the Gilmore City Research Facility for Crop Years 2005-2009.

Treatment Number*	Treatment	Nitrogen Application Time	Nitrogen Application Rate (lb/acre)
1,2	Conventional tillage	Fall	75
3,4	Conventional tillage	Fall	125
5,6	Conventional tillage	Spring (early season sidedress)	75
7,8	Conventional tillage	Spring (early season sidedress)	125
9,10	Conventional tillage	Spring (early season sidedress)	150
11,12	Strip tillage	Spring (early season sidedress)	125
13,14	Cover crops after harvest	Spring (early season sidedress)	125
15,16	LCD every other row application	Spring (early season sidedress)	125
17	Kura clover	-	no fertilizer
18	Orchardgrass + Red/Ladino clover	-	no fertilizer

* within the corn and soybean rotation treatments, even numbers are soybean and receive no nitrogen.

These treatments allow for comparison of existing questions related to lower rates of nitrogen application and the potential impacts of fall nitrogen fertilizer application. Additionally, the LCD method of application is being investigated to determine if this application method can reduce nitrate leaching. Inclusion of the strip tillage system will investigate and demonstrate a minimal tillage system and assess its impacts on crop yield and nitrate leaching. Inclusion of cover crops and harvestable perennials allows for evaluating alternative cropping practices and the impact on nutrient movement and drainage. Evaluation of these alternatives is important for considering progressive methods for minimizing nutrient transport from tile-drained landscapes. The concentration and loading of nutrients exiting the various treatments will be monitored and evaluated on an annual basis and for the five year study period, 2005-2009. In addition, crop yield will be documented each year to evaluate treatment effects on yield, specifically whether there are declines in annual yield at the lower nitrogen rate applications. The evaluation of the treatment effects will be for the study period but each year will be analyzed to evaluate treatment effects on a yearly basis and after the completion of this phase of the research study. It is understood that climatic variability plays a significant role in the leaching of nutrients in the tile drained landscape.

From this, it is important to have numerous years of leaching data to evaluate the treatment effects both from a production (crop yield) perspective and a nutrient leaching perspective. The multiple years of data allows for evaluating how the treatments respond under varying climatic conditions and after subsequent years with similar cropping practices. Also, these multiple years of data allow for additional characterization of tile flow under varied precipitation conditions and allow for further understanding of the hydrology of the site.

Agronomic Activities in 2005, 2006, 2007 and 2008

Agronomic field activities were completed in a timely manner prior to and during the crop season. Rye for 2005 was seeded on October 15, 2004. Fall chisel plowing was performed on November 2-3, 2004. Fall fertilization was completed on November 15, 2004. Tillage for seedbed preparation was completed in the spring just prior to planting of perennial crops on April 18th and followed by 0.72” of precipitation. Round Up herbicide was applied on April 14, 2005 in the rye/corn system and in rye/soybean plots on May 24. Seedbed preparation for corn and soybean was also completed just prior to May 3 and 4 seeding dates. Fertilizer was applied just after corn crop emergence on May 12-13, 2005. Rye for 2006 was planted on October 11, 2005. Fall chisel plowing of corn residue was performed on November 14, 2005. Fall fertilization for 2006 was completed on November 21, 2005. Field activities in 2006 were completed in a timely manner prior to and during the crop season. Seedbed preparation for corn and soybean was completed just prior to May 4 corn seeding date. Soybean was seeded on May 10. Fertilizer was applied just after corn crop emergence on May 17-18th. Rye cover crop in corn plots was sprayed to eliminate on April 24. Soybean rye cover crop plots were sprayed to eliminate rye on May 16. Rye for 2007 was planted on October 12, 2006. Fall fertilization for 2007 was completed on November 21, 2006. Fall tillage (chisel plow of corn residue) was performed on November 22, 2006. In 2007, seedbed preparation for corn and soybean was completed just prior to May 14 corn seeding date. Soybean was seeded on May 17. Fertilizer was applied just after corn crop emergence on June 5th. Rye cover crop in corn plots was sprayed to eliminate rye on April 30. Soybean rye cover crop plots were sprayed to eliminate rye on May 23. Rye for 2008 was planted on October 25, 2007. Fall fertilization for 2008 was completed on November 13, 2007. Fall tillage (chisel plow of corn residue) was performed on November 21, 2007. In 2008, seedbed preparation for corn and soybean was completed just prior to May 14 corn seeding date. Soybean was seeded on May 19. Fertilizer was applied just after corn crop emergence on June 4th. Rye cover crop in corn plots was sprayed to eliminate rye on May 5. Soybean rye cover crop plots were sprayed to eliminate rye on May 23.

Weed Control 2005, 2006, 2007 and 2008

Round Up ready crops were used at the site in 2005. Dual II was used for pre-plant weed control and was broadcast on May 10, 2005. First application of Round Up was on May 21, 2005. Second application was on June 17, 2005.Weed control was acceptable in most soybean plots; poor control of lambsquarter was noted in 6 of 32 plots, likely due to sprayer malfunction or poor herbicide application timing. Corn weed control was superior; no specific weed control problems were observed. Cultivation for weed control was not incorporated in the weed management system.

Round Up ready crops were again used at the site in 2006. Dual II was used for pre-plant weed control and was broadcast on May 22, 2006. First application of Round-Up for weed control was on May 22 for strip till plots; all other plots had first application on June 2, 2006. Second application was on June 19, 2006 in corn plots only. Soybeans had second application on June 22, 2006. Weed control was acceptable in most soybean plots; poor control of lambsquarter was noted in the strip till plots, for both corn and soybean due to poor herbicide application timing.

Corn weed control in all other treatments was superior except as mentioned in strip till plots; no specific weed control problems were observed. Cultivation for weed control was not incorporated in the weed management system.

As in the first two years, Round Up ready crops were used at the site in 2007. Dual II was used for pre-plant weed control and was broadcast on May 31. First application of Round-Up for weed control was on May 31. Second application was on June 13, 2007. Weed control was acceptable in soybean plots; poor control of lambsquarter and dandelion was noted in the strip till plots, for both corn and soybean due to poor herbicide application timing. Corn weed control in all other treatments was superior except as mentioned in strip till plots; no specific weed control problems were observed. Cultivation for weed control was not incorporated in the weed management system.

As in the first three years, Round Up ready crops were used at the site in 2008. First application of Round-Up for weed control was on May 28. Second application was on June 16-19, 2008. Weed control was acceptable in most plots; however, there was poor control of lambsquarter, grasses, and dandelion in some plots. Cultivation for weed control was not incorporated in the weed management system.

Precipitation 2005, 2006, 2007 and 2008

Precipitation was recorded at the site in 2005 from April through November; freezing weather (Jan-March and December) precipitation was obtained from NOAA weather stations in Pocahontas and Humboldt (Table 2). January through March precipitation in 2005 was slightly below normal at the site. April, May and June were each above normal (0.4” to 1.15” higher). July precipitation was nearly 2”, August nearly 3” and September 1.4” below normal. March through November total was 6.47” below normal. Highest individual storm event precipitation was on June 25-26 when 2.65” were recorded.

Table 2. Precipitation in 2005 at the Gilmore City Research Facility (GCRF) and comparisons to norms and amounts at local NOAA weather stations.

Precipitation at the GCRF in 2005				NOAA weather stations in 2005		
			normal*	Pocahontas	Humboldt	average
	mm	inches	inches		inches	
Jan	-	-	0.91	0.62	0.60	0.61
Feb	-	-	0.70	1.77	1.60	1.69
Mar	-	-	2.20	1.33	1.07	1.20
Apr	89	3.49	3.09	3.32	3.61	3.47
May	129	5.09	3.94	5.85	4.15	5.00
Jun	134	5.27	4.37	7.46	8.89	8.18
Jul	63	2.47	4.37	3.82	4.42	4.12
Aug	45	1.76	4.60	1.41	3.20	2.31
Sep	39	1.53	3.16	3.38	4.54	3.96
Oct	20	0.79	2.17	1.00	0.59	0.80
Nov	43	1.69	1.86	1.50	2.18	1.84
Dec	-	-	1.37	1.54	1.23	1.39
total			32.74	33.00	36.08	34.54

* From: Climatological Data for Iowa, National Climate Data Center for Pocahontas Iowa 1971-00.

Precipitation was recorded at the site in 2006 from March through November; freezing weather (Jan-Feb and December) precipitation was obtained from NOAA weather stations in Pocahontas and Humboldt (Table 3). January and February precipitation was slightly below normal. March and April were each above normal (0.51 and 0.57" higher). May, June and July were all well below normal, with August and September slightly above normal. March through November total was 8.59" below normal. Highest individual storm event precipitation was on August 9 when 2.32" was recorded.

Table 3. Precipitation in 2006 at the research site and comparisons to norms and amounts at local NOAA weather stations.

Precipitation at the GCRF in 2006				NOAA weather stations in 2006		
			normal*	Pocahontas	Humboldt	average
	mm	inches	inches		inches	
Jan	-	-	0.91	0.46	0.45	0.46
Feb	-	-	0.70	0.43	0.54	0.49
Mar	69	2.71	2.20	3.74	2.87	3.31
Apr	93	3.66	3.09	4.22	3.54	3.88
May	14	0.87	3.94	0.92	2.08	1.50
Jun	56	2.39	4.37	1.58	1.96	1.77
Jul	26	1.10	4.37	2.64	1.79	2.22
Aug	46	5.30	4.60	5.01	4.39	4.70
Sep	56	3.60	3.16	3.18	4.50	3.84
Oct	19	0.76	2.17	0.70	1.46	1.08
Nov	20	0.78	1.86	1.36	1.36	1.36
Dec	-	-	1.37	1.69	2.04	1.87
total			32.74	25.93	26.98	26.48

* From: Climatological Data for Iowa, National Climate Data Center for Pocahontas Iowa 1971-00

Precipitation was recorded at the site in 2007 from March through November; freezing weather (Jan-Feb and December) precipitation was obtained from NOAA weather stations in Pocahontas and Humboldt (Table 4). January, February, April and May precipitation was above normal. March was slightly below normal. As in 2006, June and July were both well below normal, with August 8.62" above normal and September and October only slightly above normal. March through November total was 3.52" above normal. Highest individual storm event precipitation was on August 21 when 3.70" was recorded.

Precipitation was recorded at the site in 2008 from March through November; freezing weather (Jan-Feb, part of November and December) precipitation was obtained from NOAA weather stations in Pocahontas and Humboldt (Table 5). January and March precipitation was below normal; however, February and April through June precipitation was above normal. July precipitation was comparable to normal. The lower precipitation amounts in August and September were countered by higher rainfall in October.

Table 4. Precipitation in 2007 at the research site and comparisons to norms and amounts at local NOAA weather stations.

Precipitation at the GCRF in 2007				NOAA weather stations in 2007		
			normal*	Pocahontas	Humboldt	average
	mm	inches	inches		inches	
Jan	-	-	0.91	1.20	1.44	1.32
Feb	-	-	0.70	1.57	1.54	1.56
Mar	46	1.80	2.20	2.31	2.20	2.25
Apr	83	3.27	3.09	4.09	4.70	4.40
May	90	3.54	3.94	4.68	4.38	4.53
Jun	44	1.75	4.37	1.62	2.58	2.10
Jul	41	1.63	4.37	1.19	2.84	2.02
Aug	336	13.22	4.60	13.01	16.68	14.85
Sep	97	3.82	3.16	3.27	2.95	3.11
Oct	107	4.22	2.17	4.23	4.32	4.28
Nov	1	0.03	1.86	0.05	0.05	0.05
Dec	-	-	1.37	1.86	1.48	1.67
total			32.74	39.08	45.16	42.12

* From: Climatological Data for Iowa, National Climate Data Center for Pocahontas Iowa 1971-00

Table 5. Precipitation in 2008 at the research site and comparisons to norms and amounts at local NOAA weather stations.

Precipitation at the GCRF in 2008				NOAA weather stations in 2008		
			normal*	Pocahontas	Humboldt	average
	mm	inches	inches		inches	
Jan	-	-	0.91	0.50	0.56	0.53
Feb	-	-	0.7	1.24	0.96	1.10
Mar	35	1.37	2.2	1.34	0.86	1.10
Apr	88	3.45	3.09	3.34	5.02	4.18
May	151	5.96	3.94	6.88	5.97	6.43
Jun	152	5.97	4.37	5.67	9.40	7.54
Jul	105	4.12	4.37	5.37	3.85	4.61
Aug	80	3.16	4.6	2.08	1.52	1.80
Sep	65	2.55	3.16	1.94	1.84	1.89
Oct	100	3.94	2.17	4.01	3.82	3.92
Nov	37	1.46	1.86	1.65	1.80	1.73
Dec	-	-	1.37	NA	NA	NA
total			32.74			

* From: Climatological Data for Iowa, National Climate Data Center for Pocahontas Iowa 1971-00
NA – Not available at time of report preparation

Drainage 2005, 2006, 2007 and 2008

Average soil temperature at a 4” depth rose above freezing in 2005 on March 22 and continued to rise. Treatment plot sampling pumps were installed during the last week of March. Drainage started during this period and the first samples were collected on April 1st. Eighteen of the seventy-two plots had enough drainage to provide a sample on this date. By April 7th, fourteen additional plots were sampled. Samples were collected on at least a weekly basis, and for most plots, drainage was sufficient for sampling through the month of June. Only ten plots had drainage in July; the last samples were gathered on July 26th. Table 6 lists drainage volumes by treatment in 2005 with statistical differences at p=0.05. Five of the eighteen treatments had one of four replications removed due to excessive drainage volume values. Statistical differences among treatments were noted for four of eighteen treatments (LSD=7.22 inches). Average drainage for all treatments was 8.45 inches. When the treatments were grouped by crop (C vs. S) it was noted that there was a significant difference between crops, with soybean having a lower value (C=10.17", S=7.19") possibly related to tillage operations performed prior to the drainage season. With 23.29" of precipitation between March 1 and November 30 and using an overall drainage volume of 8.45", approximately 36% of the precipitation became subsurface drainage. Nearly half of the precipitation amount that occurred between March and the end of July, when drainage ceased, became subsurface drainage (see Table 6). The site was winterized on December 5. Average soil temperature at 4" depth did not drop below freezing in December 2005 in the region.

Average soil temperature at a 4"depth rose above freezing in 2006 on March 11 and remained steady and began to rise after the 17th of March. Treatment plot sampling pumps were installed on March 28th. After installation, 0.92" of rainfall was recorded on March 30-31st, 2006 and subsurface drainage began thereafter and the first samples were collected on April 1st. Forty-nine of the seventy-two plots had enough drainage to provide a sample on this date. Samples were collected on at least a weekly basis, and for most plots, drainage was sufficient for sampling through the first week of May. All drainage ceased on May 10, 2006. Table 6 lists drainage volumes by treatment in 2006 with statistical differences at p=0.05. Nine of the eighteen treatments had one of four replications removed due to erroneous (usually excessive because of pump malfunction in an adjacent sump) drainage volume values. No statistical differences among treatments were noted for drainage in 2006 (LSD=2.08 inches). Average drainage for all treatments was 3.60 inches. When the treatments were grouped by crop, no significant difference between crops was noted as was in 2005. With 15.70" of precipitation between March 1 and November 30 and using an overall drainage volume of 3.60", approximately 23% of the precipitation became subsurface drainage. Nearly half of the precipitation amount that occurred between March and the middle of May, when drainage ceased, became subsurface drainage (see Table 7). The site was winterized on November 28, 2006. Average soil temperature at 4" depth fell below freezing on December 3, 2006.

Table 6. Subsurface drainage volumes with statistical differences at p=0.05, by treatment in 2005, 2006, 2007 and 2008. Statistical comparisons are within years only.

Treatment	Description	Drainage (inches)			
		2005	2006	2007	2008
1	Fall 75 Corn (c-s)	12.03a	3.33a	21.01a	19.43a
2	Fall 75 Soybean (s-c)	7.14ab	3.81a	20.03a	17.62a
3	Fall 125 Corn (c-s)[3,4]	11.07ab	3.85a	19.98a	17.21a
4	Fall 125 Soybean (s-c)[1,2,4]	7.31ab	3.23a	14.94a	15.20a
5	Spring 75 Corn (c-s)	11.72ab	3.63a	22.66a	19.30a
6	Spring 75 Soybean (s-c)	5.27ab	3.52a	17.96a	16.61a
7	Spring 125 Corn (c-s)[1,2,4]	4.70b	3.67a	19.22a	12.02a
8	Spring 125 Soybean (s-c)[2]	5.95ab	3.08a	15.09a	16.47a
9	Spring 150 Corn (c-s)[2]	12.49a	3.07a	22.77a	19.05a
10	Spring 150 Soybean (s-c)[2]	7.55ab	4.21a	20.63a	17.44a
11	Strip 125 Corn (c-s)[1,2,4]	9.70ab	3.91a	22.03a	16.65a
12	Strip 125 Soybean (s-c)[1,4]	4.80b	4.56a	17.70a	15.36a
13	Cover Crop 125 Corn (c-s)[1,2]	6.98ab	3.30a	21.45a	17.29a
14	Cover Crop 125 Soybean (s-c)[2]	10.53ab	3.70a	22.71a	20.32a
15	LCD 125 Corn (c-s)	9.65ab	4.04a	20.58a	18.22a
16	LCD 125 Soybean (s-c)	6.78ab	3.51a	21.73a	15.81a
17	Kura clover	10.08ab	3.59a	21.17a	18.49a
18	Orchardgrass + Red/Ladino clover[2,4]	8.29ab	2.62a	17.19a	15.15a
LSD		7.22	2.08	10.51	10.40
average drainage		8.45	3.6	19.94	17.09
standard deviation		2.53	1.43	2.45	1.98
average for corn treatments		10.17	3.67	21.21	17.40
average for soybean treatments		7.19**	3.62	18.85	16.85

[1] one of four reps not included in 2005 because of erroneous drainage value.
[2] one of four reps not included in 2006 because of erroneous drainage value.
[3] one of four reps not included in 2007 because of erroneous drainage value.
[4] one of four reps not included in 2008 because of erroneous drainage value.
** significantly different from drainage for corn treatments at p=0.05.
The (c-s) or (s-c) indicates the rotation order starting in 2005.

Average soil temperature at a 4”depth rose above freezing in 2007 on March 13 and remained steady and began to rise after the 17th of March. Treatment plot sampling pumps were installed on March 20th. After installation, 0.60” of rainfall was recorded on March 21-24th, 2007 and subsurface drainage began thereafter and the first samples were collected on March 26th. Forty of the seventy-two plots had enough drainage to provide a sample on this date. Samples were collected on at least a weekly basis, and for most plots, drainage was sufficient for sampling through the first week of June. All drainage ceased after the 1st week of June and commenced the third week of August after 10.5 inches was recorded in the preceding week. At least weekly samples were also available from the 3rd week of September until the end of October, a rather atypical drainage period. Table 6 lists drainage volumes by treatment in 2007 with statistical differences at p=0.05. Only one of the eighteen treatments had one of four replications removed due to erroneous (usually excessive, because of pump malfunction in an adjacent sump) drainage volume values. All other replications were used in statistical analysis. No statistical differences among treatments were noted for drainage in 2007 (LSD=10.51 inches). Average drainage for all treatments was 19.94 inches (5.5x the drainage of 2006 and 2.4x that of 2005). When the treatments were grouped by crop, no significant difference between crops was noted. With 33.28" of precipitation between March 1 and November 30 and using an overall drainage volume of 20.38", approximately 61% of the precipitation became subsurface drainage. April and October both had more drainage than precipitation, likely caused by drainage delay from the previous month's precipitation (see Table 7). The site was winterized on November 19, 2007. Average soil temperature at 4" depth fell below freezing on November 28, 2007.

Average soil temperature at a 4"depth rose above freezing in 2008 on March 22 and steadily began to rise. Treatment plot sampling pumps were installed on March 17th. Subsurface drainage for most plots began between March 25th and April 1st with the first samples (6) being collected on March 25th. Forty-two of the seventy-two plots had enough drainage to provide a sample on April 1st. Samples were collected on at least a weekly basis, and for most plots, drainage was sufficient for sampling through the third week of June. All drainage ceased after the 1st week of July but a storm the middle part of July produced another round of sampling. Samples started to be collected again the second week of October and commenced the third week of November. Table 6 lists drainage volumes by treatment in 2008 with statistical differences at p=0.05. Six of the eighteen treatments had one of four replications removed due to erroneous (usually excessive) drainage volume values. All other replications were used in statistical analysis. No statistical differences among treatments were noted for drainage in 2008 (LSD=10.40 inches). Average drainage for all treatments was 18.78 inches (0.94x the drainage of 2007, 5.22x the drainage of 2006 and 2.22x that of 2005). With 31.99" of precipitation between March 1 and November 30 and using an overall drainage volume of 18.78", approximately 59% of the precipitation became subsurface drainage. June had much more drainage than precipitation; however there was a 3" rainfall at the very end of May, which would cause substantial drainage in early June (see Table 7). The site was winterized between October 27 and November 17, 2008. Average soil temperature at 4" depth fell below freezing on December 6, 2008.

Table 7. Average annual drainage for each month over all treatments with totals and percentage as drainage for April-July 2005, 2006, 2007and 2008.

	2005			2006			2007			2008		
	precip	drainage	%	precip	drainage	%	precip	drainage	%	precip	drainage	%
	------ inches ------			------ inches ------			------ inches -----			------ inches -----		
March	1.2	-	0	2.71	-	0	1.8	0.49	27	1.37	0.01	0
April	3.49	2.82	81	3.66	2.38	65	3.27	4.38	134	3.45	4.11	119
May	5.09	3.23	63	0.87	1.62	186	3.54	1.41	40	5.96	3.75	63
June	5.27	2.46	47	2.39	-	0	1.75	0.24	14	5.97	9.33	156
July	2.47	0.12	5	1.1	0.22	0	1.63	-	0	4.12	0.17	4
August	1.76	-	0	5.3	-	0	13.22	8.20	62	3.16	0.00	0
September	1.53	-	0	3.6	-	0	3.82	0.14	4	2.55	0.00	0
October	0.79	-	0	0.76	-	0	4.22	5.52	131	3.94	0.66	17
total	21.6	8.63	40	20.39	4.22	21	33.25	20.38	61	30.53	18.02	59

Nitrate Concentrations and Losses 2005, 2006, 2007 and 2008

Previous history of current plot treatments quite likely has influenced the nitrate-nitrogen concentrations observed during 2005 and to some extent those in 2006. The majority of plots received 150 or 200 lbs N/acre during the period of 2000-2004 either as manure or aqua ammonia in the spring or fall. Some plots would have received 225 lbs of ammonia, each season. The previous experimental phase also included a split plot methodology with both corn and soybean grown on each plot, as opposed to the current phase utilizing whole plots, which has also contributed to and confounded the 2005 results. No definitive treatment effect trends should be derived from 2005 concentration results. Some treatment effect trends began to emerge in 2006.

In 2005, 535 flow weighted water samples were gathered. Table 8 lists the treatment results. Only the highest and three lowest average concentrations, out of eighteen compared, exhibited significant differences at p=0.05 level. The highest NO_3-N average concentration (18.8 mg/L NO_3-N) was observed in a treatment that was in the soybean year of the rotation and received no nitrogen in 2005. In the previous phase, two of the four replications for this treatment received 225 lbs N/acre and is quite likely a major factor in the elevated levels of NO_3-N observed. Lowest concentration observed was for two treatments: strip tillage 125 and LCD 125 cropped to corn, both averaged 12.9 mg/L NO_3-N.

The highest concentrations in 2006 were recorded for the 150 rate treatment within the soybean year (N applied in 2005 and years prior) and lowest were found in the perennial systems, specifically the Kura clover treatment; all other values were between these treatments values. Annual flow-weighted concentrations ranged from 6.9 to 21.7 mg L^{-1}. Individual, flow weighted averages ranged from 4.5 to 30.1 mg L^{-1} and were recorded within the aforementioned treatments. Average flow weighted values for most treatments only showed minor differences in their NO_3-N concentrations when compared. No significant differences were noted when comparing the fall and spring applications to each other across rates or crops or when rates were compared within the spring application rate treatment only. Use of the LCD applicator compared to a conventional knife also showed no significant differences in resulting concentrations. The use of a cover crop or strip tillage system in either crop also did not exhibit any significant effects on NO_3-N concentrations. The only significance was shown when comparing the N rate treatments within the soybean year of the corn soybean cropping system; nitrate in drainage from the previous season(s) applications at the 150 rate was significantly different than the 75 and 125 rates. Table 8 lists all treatments by year and the statistical differences at the p=0.05 level.

As opposed to 2006, highest concentrations in 2007 were recorded for the 150 rate treatment within the corn year (concentrations were highest in the soybean year in 2006 for the 150 rate) and lowest were found in the perennial systems, specifically the orchardgrass/clover treatment; all other values were between these treatments values. Annual flow-weighted concentrations ranged from 4.4 to 20.3 mg L^{-1}. Individual plot/replication, flow weighted averages ranged from 2.2 to 23.6 mg L^{-1} and were recorded within the aforementioned treatments. Average flow weighted values for most treatments only showed minor differences in their NO_3-N concentrations when compared. No significant differences were noted when comparing the fall and spring applications to each other across rates or crops. Use of the LCD applicator compared to a conventional knife also showed no significant differences in resulting concentrations. The use of a cover crop or strip tillage system in either crop also did not exhibit any significantly different effects on NO_3-N concentrations. However, while not significantly different, on an absolute basis NO_3-N concentrations were between 9% and 23% lower in the treatments with winter cover crops. Significance was noted when comparing the N rate treatments. Nitrate in drainage from the previous season(s) applications at the 150 rate was significantly different than the 75 and 125 rates. Table 8 lists all treatments by year and the statistical differences at the p=0.05 level.

Just like in 2007, highest concentrations in 2008 were recorded for the 150 rate treatment (treatment 9); however, 2008 was a soybean year as opposed to corn in 2007 and lowest were found in the perennial systems, specifically the orchardgrass/clover treatment (treatment 18); all other concentrations were between these treatments values. Annual flow-weighted concentrations ranged from 3.0 to 20.1 mg L^{-1}. Individual plot/replication, flow weighted averages ranged from 1.0 to 24.6 mg L^{-1} and were recorded within the aforementioned treatments. No significant differences were noted when comparing the fall and spring applications to each other across rates or crops. Use of the LCD applicator compared to a conventional knife also showed no significant differences in resulting concentrations. Treatment 14, which is a cover crop in corn for 2008, had a significantly lower NO_3-N concentration than treatment 4, fall application in corn for 2008. Treatment 14 was not significantly lower than other comparable spring application treatments (treatments 8, 12, 16). Treatment 13, cover crop in soybeans for 2008 was not significantly different than any comparable treatments (treatments 3, 7, 11, 15). The strip tillage system in either crop did not exhibit any significantly different effects on NO_3-N concentrations. Significance was noted when comparing the N rate treatments. Treatment 9, which was planted with soybeans in 2008, had the highest nitrate concentrations of all treatments. Table 8 lists all treatments by year and the statistical differences at the p=0.05 level.

Table 9 lists NO_3-N losses by treatment in 2005, 2006, 2007 and 2008. Losses were calculated by multiplying subsurface drainage effluent concentration by drainage volume. Due to the inherent variability between experimental plots and among treatments, loss calculations for one year may not be the best indicator of treatment effect. Losses in 2005 ranged from 17.4 lbs/acre NO_3-N for soybean grown under a strip tillage system, with no fertilizer added in 2005 to 41.1

lbs/acre NO_3-N exiting the subsurface drainage system for an early season sidedress application of 150 lbs N/acre on corn. (Fertilizer was applied on May 12-13.) These two treatments were the only statistically different (p=0.05) treatments for loss in 2005.

Table 8. Average annual flow weighted nitrate concentrations by treatment in 2005, 2006, 2007 and 2008 with statistical significance at p=0.05. Statistical comparisons are within years only.

Treatment	Description	Nitrate N	(mg/L)	p=0.05	
		2005	2006	2007	2008
1	Fall 75 Corn (c-s)	14.5ab	10.4efg	10.6cd	9.5f
2	Fall 75 Soybean (s-c)	17.8ab	17.3abc	11.1bcd	15.7b
3	Fall 125 Corn (c-s)	14.5ab	14.0bcdef	13.8b	11.5ef
4	Fall 125 Soybean (s-c)	13.5ab	16.0bcd	11.6bcd	14.9bc
5	Spring 75 Corn (c-s)	13.5ab	12.0def	10.0de	9.7f
6	Spring 75 Soybean (s-c)	18.8a	18.3ab	13.5bc	14.5bcd
7	Spring 125 Corn (c-s)	18.1ab	13.6bcdef	12.9bcd	12.1def
8	Spring 125 Soybean (s-c)	17.0ab	15.4bcd	12.9bcd	13.0bcde
9	Spring 150 Corn (c-s)	16.3ab	21.7a	20.3a	20.1a
10	Spring 150 Soybean (s-c)	15.8ab	15.7bcd	17.6a	15.8b
11	Strip 125 Corn (c-s)	12.9b	13.4cdef	11.5bcd	9.9f
12	Strip 125 Soybean (s-c)	14.2ab	14.1bcdef	11.4bcd	12.1def
13	Cover Crop 125 Corn (c-s)	13.9ab	11.4defg	11.7bcd	12.3cdef
14	Cover Crop 125 Soybean (s-c)	14.4ab	15.2bcd	9.9de	11.4ef
15	LCD 125 Corn (c-s)	12.9b	12.8cdef	12.1bcd	12.4cdef
16	LCD 125 Soybean (s-c)	16.1ab	14.8bcde	11.3bcd	13.3bcde
17	Kura clover	13.1b	6.9g	7.4ef	6.1g
18	Orchardgrass + Red/Ladino clover	14.7ab	9.7fg	4.4f	3.0h
	LSD	5.4	4.8	3.2	2.8

The (c-s) or (s-c) indicates the rotation order starting in 2005.

Losses in 2006 were much below those recorded in 2005 not because of a major drop in concentrations (except for the perennial systems, which did drop substantially) but because drainage volumes were approximately 42% of those recoded in 2005. Losses ranged from 5.2 to 16.5 lbs/acre for the Kura clover treatment and 150 spring applied nitrogen treatment in the soybean year of the rotation, respectively (N applied on May 12-13, 2005 in the corn year). Statistical differences were noted when comparing the spring 150 soybean treatment to both the fall 75 soybean and the perennial systems as listed in Table 9.

Losses in 2007 were the highest recorded since the initiation of this treatment phase in 2005. The increase in loss was due to large drainage volumes in 2007 compared to previous years. Average drainage volume was 2.3 times that recorded in 2005 (5.5 times that of 2006) and the losses increased accordingly. Losses ranged from 18.6 to 101.6 lbs N/acre for the Kura clover treatment and 150 spring applied nitrogen treatment in the corn year of the rotation, respectively (N applied on June 5, 2007 in the corn year). One-third of the 150 rate loss in corn was prior to N application in 2007. Statistical difference was noted when comparing the spring 150 corn treatment compared to all other treatments except for the soybean 150 treatment as listed in Table 9.

Losses in 2008 were slightly lower than in 2007. This follows the drainage volume trend (Table 7) with 2008 drainage being slightly less (~2 inches) than in 2007. Losses ranged from 9.0 to 84.3 lbs N/acre for the Kura clover treatment and 150 spring applied nitrogen treatment in the soybean year of the rotation, respectively (N applied on June 5, 2007 in the corn year). Statistical difference was noted when comparing treatments 9 and 10, the corn soybean rotation receiving 150 lb/acre N in the corn years, compared to all other treatments except for treatment 2 which was planted with corn in 2008. All statistical comparisons are listed in Table 9.

Table 9. Average annual flow weighted nitrate losses by treatment in 2005, 2006, 2007 and 2008 with statistical significance at p=0.05. Statistical comparisons are within years only.

Treatment	Description		Nitrate-N	(lb/acre)	
		2005	2006	2007	2008
1	Fall 75 Corn (c-s)	38.4ab	8.0bc	51.2c	42.4bc
2	Fall 75 Soybean (s-c)	23.9ab	15.3ab	49.9c	62.4ab
3	Fall 125 Corn (c-s)	35.4ab	12.4abc	63.6bc	44.4bc
4	Fall 125 Soybean (s-c)	23.7ab	11.4abc	39.4cd	52.6bc
5	Spring 75 Corn (c-s)	35.3ab	10.3abc	52.3c	43.5bc
6	Spring 75 Soybean (s-c)	23.6ab	14.3ab	53.1c	53.0bc
7	Spring 125 Corn (c-s)	21.8ab	13.0abc	58.4bc	36.3bcd
8	Spring 125 Soybean (s-c)	23.7ab	11.5abc	44.1cd	44.2bc
9	Spring 150 Corn (c-s)	41.1a	16.5a	101.6a	84.3a
10	Spring 150 Soybean (s-c)	27.7ab	13.4abc	85.9ab	64.2ab
11	Strip 125 Corn (c-s)	27.8ab	12.0abc	55.5c	41.0bc
12	Strip 125 Soybean (s-c)	17.4b	14.2ab	43.9d	48.6bc
13	Cover Crop 125 Corn (c-s)	20.0ab	9.4abc	55.4c	37.2bcd
14	Cover Crop 125 Soybean (s-c)	34.9ab	12.6abc	48.4cd	50.1bc
15	LCD 125 Corn (c-s)	29.7ab	11.4abc	56.1bc	50.2bc
16	LCD 125 Soybean (s-c)	24.5ab	11.5abc	53.1c	47.2bc
17	Kura clover	26.3ab	5.2c	34.6cd	24.9cd
18	Orchardgrass + Red/Ladino clover	26.1ab	5.3c	18.6d	9.0d
	LSD	22.9	8.4	30.4	31.0

The (c-s) or (s-c) indicates the rotation order starting in 2005.

Total Reactive Phosphorus 2005, 2006, 2007 and 2008

Total reactive phosphorus (TRP) concentrations were measured in tile drainage samples that were also tested for NO_3-N. Table 10 lists TRP concentrations by year for each treatment. Table 11 lists loss by year and treatment in grams per acre. The ascorbic acid method of phosphorus analysis from Standard Methods for the Examination of Water and Wastewater 20th edition was used to determine the concentration of TRP, also known as total orthophosphate. The test measures both dissolved and suspended orthophosphate. This test measures the form most available to plants and is a useful indicator of potential water quality impacts such as algae blooms and weed growth in surface waters. No specific trends were observed over the four year period of observation. Due to the low levels of phosphorus leaving the plots and limits on sample analysis precision, it is not possible to draw meaningful conclusions about this data. Analyses of 2008 water samples for TRP are being completed and will be reported when available.

Table 10. Average annual flow weighted total reactive phosphorus concentrations by treatment in 2005, 2006, 2007, and 2008 data with statistical significance at p=0.05. Statistical comparisons are within years only.

Treatment	Description	TRP	(µg/L)	p=0.05	
		2005	2006	2007	2008
1	Fall 75 Corn (c-s)	4.64cd	6.00b	14.56b	53.00a
2	Fall 75 Soybean (s-c)	6.68cd	12.18ab	9.44b	13.20b
3	Fall 125 Corn (c-s)	25.29a	9.99ab	9.62b	17.70ab
4	Fall 125 Soybean (s-c)	17.24abc	11.19ab	47.74a	37.38ab
5	Spring 75 Corn (c-s)	15.03abcd	7.84b	9.60b	21.47ab
6	Spring 75 Soybean (s-c)	8.58cd	6.47b	8.23b	10.39b
7	Spring 125 Corn (c-s)	10.56cd	11.73ab	10.18b	22.14ab
8	Spring 125 Soybean (s-c)	22.63ab	14.04ab	52.16a	51.51a
9	Spring 150 Corn (c-s)	13.85bcd	9.31ab	6.45b	9.06b
10	Spring 150 Soybean (s-c)	11.31cd	9.31ab	10.10b	12.02b
11	Strip 125 Corn (c-s)	9.84cd	9.28ab	13.36b	10.43b
12	Strip 125 Soybean (s-c)	6.94cd	9.05b	10.19b	9.56b
13	Cover Crop 125 Corn (c-s)	11.96bcd	10.69ab	23.85ab	21.66ab
14	Cover Crop 125 Soybean (s-c)	13.80bcd	17.12a	16.56b	15.18b
15	LCD 125 Corn (c-s)	12.63bcd	6.71b	8.15b	17.84ab
16	LCD 125 Soybean (s-c)	12.12bcd	9.54ab	8.89b	8.98b
17	Kura clover	9.69cd	12.09ab	7.87b	10.12b
18	Orchardgrass + Red/Ladino clover	7.11cd	11.02ab	7.39b	7.75b
	LSD	11.3	8.1	29.4	35.8

The (c-s) or (s-c) indicates the rotation order starting in 2005.

Table 11. Average annual flow weighted total reactive phosphorus loss by treatment in 2005, 2006, 2007, and 2008 data with statistical significance at p=0.05. Statistical comparisons are within years only.

Treatment	Description	TRP	(grams/acre)	p=0.05	
		2005	2006	2007	2008
1	Fall 75 Corn (c-s)	6.4b	2.3c	29.7bc	75.80a
2	Fall 75 Soybean (s-c)	4.3b	4.3abc	18.7c	20.51b
3	Fall 125 Corn (c-s)	19.2ab	4.1abc	18.4c	33.82ab
4	Fall 125 Soybean (s-c)	14.3ab	3.3abc	72.4a	51.53ab
5	Spring 75 Corn (c-s)	13.0ab	2.8c	21.4c	43.01ab
6	Spring 75 Soybean (s-c)	5.0b	2.4c	14.4c	15.59b
7	Spring 125 Corn (c-s)	6.2b	5.6abc	23.7c	14.45b
8	Spring 125 Soybean (s-c)	14.8ab	6.4ab	70.9ab	47.97ab
9	Spring 150 Corn (c-s)	15.4ab	4.2abc	14.7c	18.71b
10	Spring 150 Soybean (s-c)	8.6ab	4.4abc	20.1c	15.64b
11	Strip 125 Corn (c-s)	25.7a	3.4abc	33.6abc	15.14b
12	Strip 125 Soybean (s-c)	3.0b	3.1bc	21.4c	10.02b
13	Cover Crop 125 Corn (c-s)	20.6ab	4.9abc	41.7abc	23.76ab
14	Cover Crop 125 Soybean (s-c)	12.5ab	4.1abc	34.0abc	37.67ab
15	LCD 125 Corn (c-s)	13.2ab	6.7a	16.0c	31.20ab
16	LCD 125 Soybean (s-c)	8.3ab	3.2bc	22.0c	13.73b
17	Kura clover	9.6ab	3.1bc	17.8c	22.03ab
18	Orchardgrass + Red/Ladino clover	5.9b	2.7c	13.9c	11.27b
	LSD	19.1	3.4	41.5	55.2

The (c-s) or (s-c) indicates the rotation order starting in 2005.

Late Spring Nitrate Test 2005, 2006, 2007 and 2008

Each corn plot was sampled using the Late Spring Nitrate Test (LSNT) procedures for determination of nitrate-nitrogen concentrations in the top 12” of soil on June 17, 2005 when corn plants were approximately 10” tall. Table 12 lists soil test results and the additional application amount recommended. Test results were for information only and no additional N applications were made. Fall N application plots had lower test values than plots with N applied in the spring. The spring 150 (treatment 9) plots had the highest N concentrations and the fall 125 (treatment 3) the lowest.

Each corn plot was sampled using the Late Spring Nitrate Test (LSNT) procedures for determination of nitrate-nitrogen concentrations in the top 12” of soil on June 6, 2006 when corn plants were approximately 8” tall. Results are listed in Table 12. As in 2005, test results were for information purposes only. No additional N was applied to the treatment plots. Highest values were observed using the LCD applicator at 125 lbs/acre N rate, closely followed by the conventional knife applicator using 150 lbs N/acre. Lowest values were recorded for the Fall 75 treatment.

Each corn plot was sampled using the Late Spring Nitrate Test (LSNT) procedures for determination of nitrate-nitrogen concentrations in the top 12” of soil on June 4, 2007 when corn plants were approximately 6” tall and prior to fertilizer application. Results are listed in Table 12. As in previous years, test results were for information purposes only. No additional N based on LSNT results was applied to the treatment plots. Highest values, 10 mg/L were observed for 3 of the 8 treatments (LCD, Strip, and Fall at 125 lbs/acre N rate), closely followed by all other treatments at 8 mg/L.

Due to a very wet May, and fertilization on June 4, 2008, a specific LSNT was not completed in 2008; however, soil samples for half of the corn plots were taken in late April, the results of which are listed in Table 12. As in previous years, test results were for information purposes only. No additional N based on LSNT results was applied to the treatment plots.

Table 12. Late Spring Nitrate Test (LSNT) nitrate-N concentrations and additional N recommended but not applied in 2005, 2006, 2007 and 2008.

Odd treatments correspond to ODD years, even to EVEN years. Example: treatment one was measured in 2005)

		Soil Nitrate-N	Recom. N Add.	Soil Nitrate-N	Recom. N Add.	Soil Nitrate-N	Recom. N Add.	Soil Nitrate-N	Recom. N Add.
Treatments	Description	mg/kg	lb/acre	mg/kg	lb/acre	mg/kg	lb/acre	mg/kg	lb/acre
		2005		2006		2007		2008*	
1,2	Fall 75 Corn	8	136	12	106	8	136	NA	NA
3,4	Fall 125 Corn	6	150	17	62	10	122	21	30
5,6	Spring 75 Corn	10	122	19	52	8	136	NA	NA
7,8	Spring 125 Corn	9	132	26	0	8	136	5	159
9,10	Spring 150 Corn	18	54	48	0	8	136	6	154
11,12	Strip 125 Corn	10	122	16	72	10	122	NA	NA
13,14	Cover Crop 125 Corn	10	122	40	0	8	122	6.2	150
15,16	LCD 125 Corn	16	72	53	0	10	122	NA	NA

*April samples used due to high field moisture in May of 2008.
NA – Data not available

Stalk Nitrate Test 2005, 2006, 2007 and 2008

Corn stalk nitrate test sampling protocols were followed to determine nitrate-N concentrations in corn stalk tissue from each plot. Results are listed in Table 13. Stalks were sampled on September 29, 2005. Stalk nitrate values can be divided into four categories: low (less than 250 mg/L-N) marginal (250-700) optimal (700 and 2000 mg/Kg). Only the spring 150 treatment was in the optimal range, all other treatments were in the marginal to low range.

As in 2005, corn stalk nitrate test sampling protocols were followed in the fall of 2006 to determine nitrate-N concentrations in corn stalk tissue from each plot. Results are listed in Table 13 by treatment. Stalks were sampled on October 2, 2006. All treatments were in the marginal to low range indicating that additional N should have been supplied to the crop.

As in previous years, corn stalk nitrate test sampling protocols were followed in the fall of 2007 to determine nitrate-N concentrations in corn stalk tissue from each plot. Results are listed in Table 13 by treatment. Stalks were sampled on October 4-5, 2007. One-half of the treatments were in the marginal to low range indicating that additional N should have been supplied to the crop. The other half were in the optimal range: fall 125, spring 125, spring 150, and cover crop 125 treatments.

As in previous years, corn stalk nitrate test sampling protocols were followed in the fall of 2008 to determine nitrate-N concentrations in corn stalk tissue from each plot. Results are listed in Table 13 by treatment. Stalks were sampled on October 9, 2008. All treatments except for the spring applied N at 150 lb/acre were in the low range indicating that additional N would likely have made crop yields increase.

Table 13. Stalk nitrate test concentrations in 2005, 2006, 2007 and 2008. Optimal range is between 700 and 2000 mg/L-N.

Odd treatments correspond to ODD years, even to EVEN years. Example: treatment one was measured in 2005)

Treatments	Description	Nitrate-N*	mg/kg		
		2005	2006	2007	2008
1,2	Fall 75 Corn	32	238	404	142
3,4	Fall 125 Corn	67	484	718	56
5,6	Spring 75 Corn	83	171	174	38
7,8	Spring 125 Corn	186	310	867	217
9,10	Spring 150 Corn	1032	498	1450	641
11,12	Strip 125 Corn	260	228	161	182
13,14	Cover Crop 125 Corn	178	167	870	354
15,16	LCD 125 Corn	178	95	520	153

* low (less than 250 mg/Kg) marginal (250-700) optimal (700-2000).

Grain Yield 2005, 2006, 2007 and 2008

Corn and soybean yields, by treatment, are listed in Table 14 and Table 15. Because of the plot configuration in 2004, when corn and soybean were both grown on the same plot, yields for 2005 could be separated into those that followed the same crop or were grown in rotation. Continuous corn yield depression ranged from 12-31%, with an average 18%. Soybean on soybean yield depression was 6-11%, with an average of 9%. Considering only the crops in rotation, yields ranged from 156-179 bu/acre; lowest yield was for Fall 75 treatment and highest for Spring 150. The comparison resulted in a significant difference at p=0.05. All other treatments were not statistically different from these two values. Soybean yield in rotation ranged from 48-53 bu/acre and no significant differences were noted. Pocahontas County corn and soybean yield for 2005 were 183 and 50 bu/acre, respectively.

For 2006, corn yields ranged from 68-157 bu/acre; if the strip crop treatment 11(strip crop with weed pressure) was not included (68 bu/acre), lowest yield was for Fall 75 treatment (138 bu/acre) and highest for Spring 150, as was the case in 2005. In addition, when treatment 11 was removed from the statistical analysis then treatments 1 and 13 both became statistically different from the others. Even in the dry season experienced, the rye cover crop in corn only diminished yields by 4 bu/ac compared to the spring 125 treatment without rye cover. Rye in soybean only lowered yield by 1 bu/ac compared to the spring 125 treatment. Soybean yield ranged from 40-55 bu/acre. The strip crop soybean treatment had the lowest yield due to weed pressure encountered. Highest yield was for the spring 75 treatment. Overall yields at the site were very acceptable considering precipitation in the drainage season (Mar-Nov) was 8.6 inches below normal. Pocahontas County corn and soybean yield were 167 and 52 bu/acre, for 2006.

Below normal precipitation in June and July quite likely diminished corn and soybean yields in 2007. Highest corn yield was for the Fall 125 N treatment. It was closely followed by Fall 75 and Spring 150 treatments. In 2006, Fall 75 had one of the lowest yields and was equal to the yield recorded in 2007, one of the highest. The rye cover crop system showed a decrease in corn yield of 7 bu/acre compared to no cover crop. This could again be the result of below normal precipitation in June and July (~5” below normal from Mar-Jul). Soybean yield ranged from 25-37 bu/acre. Rye in soybean lowered yield by 8 bu/ac compared to the spring 125 treatment. The strip crop soybean treatment had the lowest yield due to weed pressure encountered. Highest yield was for the spring 125 N treatment. Overall yields at the site were below the county average quite likely due to below precipitation in June and July. Pocahontas County corn and soybean yield were 165 and 51 bu/acre, for 2007.

The highest observed corn yield in 2008 was for the Spring 150 lb/acre N treatment (Table 14), which also corresponds to the highest LSNT results from Table 13. It was closely followed by LCD 125 lb/acre N and Fall 125 treatments. The rye cover crop system showed an increase, although not significant, in corn yield of 8 bu/acre compared to no cover crop. Soybean yield ranged from 36-45 bu/acre. Rye in soybean lowered yield by 4 bu/ac compared to the Spring 125 treatment. Pocahontas County corn and soybean yield were not reported as of the time of this report likely due to delayed harvest in 2008.

Table 14. Corn yield by treatment in 2005, 2006, 2007, and 2008 with statistical significance at p=0.05*.

Odd treatments correspond to ODD years, even to EVEN years. Example: treatment one was measured in 2005)

Treatments	Description	2005	Yield (bu/acre) p=0.05 2005	2006	2007	2008
		continuous	rotation	rotation	rotation	rotation
1,2	Fall 75 Corn	108d	156b	138a	138ab	163a
3,4	Fall 125 Corn	137abc	164ab	147a	143a	172a
5,6	Spring 75 Corn	134bc	162ab	148a	121bcd	164a
7,8	Spring 125 Corn	153ab	173ab	143a	116cd	151a
9,10	Spring 150 Corn	156a	179a	157a	136abc	180a
11,12	Strip 125 Corn	152ab	174ab	68b	106d	166a
13,14	Cover Crop 125 Corn	134bc	163ab	139a	109d	159a
15,16	LCD 125 Corn	125cd	163ab	154a	117cd	172a
Pocahontas County average			183	167	165	NA

*significance within a system, i.e. within the rotation and within year. Note: Severe weed pressure (lambsquarter) encountered in 2006 and (dandelion) in 2007 for strip crop treatment.
NA – Data not available at time of report preparation.

Table 15. Soybean yield by treatment in 2005, 2006, 2007 and 2008 with statistical significance at p=0.05*.

Odd treatments correspond to EVEN years, even to ODD years. Example: treatment one was measured in 2006)

Treatments	Description	2005	Yield (bu/acre) p=0.05 2005	2006	2007	2008
		continuous	rotation	rotation	rotation	rotation
1,2	Fall 75 Soybean	47a	50a	43bc	36abc	36a
3,4	Fall 125 Soybean	44a	48a	50ab	37ab	45a
5,6	Spring 75 Soybean	46a	51a	55a	32bc	45a
7,8	Spring 125 Soybean	44a	49a	48ab	44a	45a
9,10	Spring 150 Soybean	47a	53a	51a	42ab	44a
11,12	Strip 125 Soybean	45a	50a	40c	25c	41a
13,14	Cover Crop 125	49a	53a	47abc	36abc	41a
15,16	LCD 125 Soybean	46a	49a	51a	36abc	42a
Pocahontas County average			50	52	51	NA

*significance within a system, i.e. within the rotation.
NA – Data not available at time of report preparation.

Rye Biomass Yield 2005, 2006, 2007 and 2008
Rye for 2005 was planted on October 15, 2004. The rye in corn plots was burned down with Round Up herbicide on April 14, 2005 and in soybean plots on May 24, 2005 to allow for these crops to flourish. Rye biomass in the soybean plots was allowed to grow 40 additional days resulting in 23.4 times as much dry matter being produced as compared to the rye in corn. Rye in corn produced 105 lbs of dry matter/acre and contained 5.5 lbs N/acre. Rye in soybean plots yielded 2464 lbs of dry matter/acre that contained 46 lbs of N/acre.

Rye for 2006 was planted on October 11, 2005 (Figure 1). That in corn plots was burned down with Round Up herbicide on April 26, 2006 and in soybean plots on May 17, 2006 to allow for these crops to flourish. Rye biomass in the soybean plots was allowed to grow 22 additional days resulting in 3.3 times as much dry matter being produced as compared to the rye in corn. Rye in corn produced 812 lbs of dry matter/acre that contained 27 lbs N/acre. Yield in soybean plots was 2672 lbs of dry matter/acre and contained 53 lbs N/acre.

Rye biomass was much lower (~63% less in corn and ~57% less in soy) (Figure 1) in 2007 compared to 2006. The decrease was quite likely due to a major growth setback as a result of very cold temperatures on April 12. Rye for 2007 was planted on October 12, 2006. That in corn plots was burned down with Round Up herbicide on May 3, 2007 and in soybean plots on May 25, 2007 to allow for these crops to flourish. Rye biomass in the soybean plots was allowed to grow 22 additional days resulting in 5 times as much dry matter being produced as compared to the rye in corn. Rye in corn produced 295 lbs of dry matter/acre that contained 10 lbs N/acre. Yield in soybean plots was 1504 lbs of dry matter/acre and contained 28 lbs N/acre.

Rye biomass in 2008 was very low (~45% less in corn and ~51% less in soy) (Figure 1) when compared to 2007. Rye for 2008 was planted on October 25, 2007. Rye in the corn plots was burned down with Round Up herbicide on May 6, 2008 and in soybean plots on May 23, 2008 to allow for these crops to flourish. Rye biomass in the soybean plots was allowed to grow 22 additional days resulting in 5 times as much dry matter being produced as compared to the rye in corn. Rye in corn produced 149 lbs of dry matter/acre. Yield in soybean plots was 676 lbs of dry matter/acre.

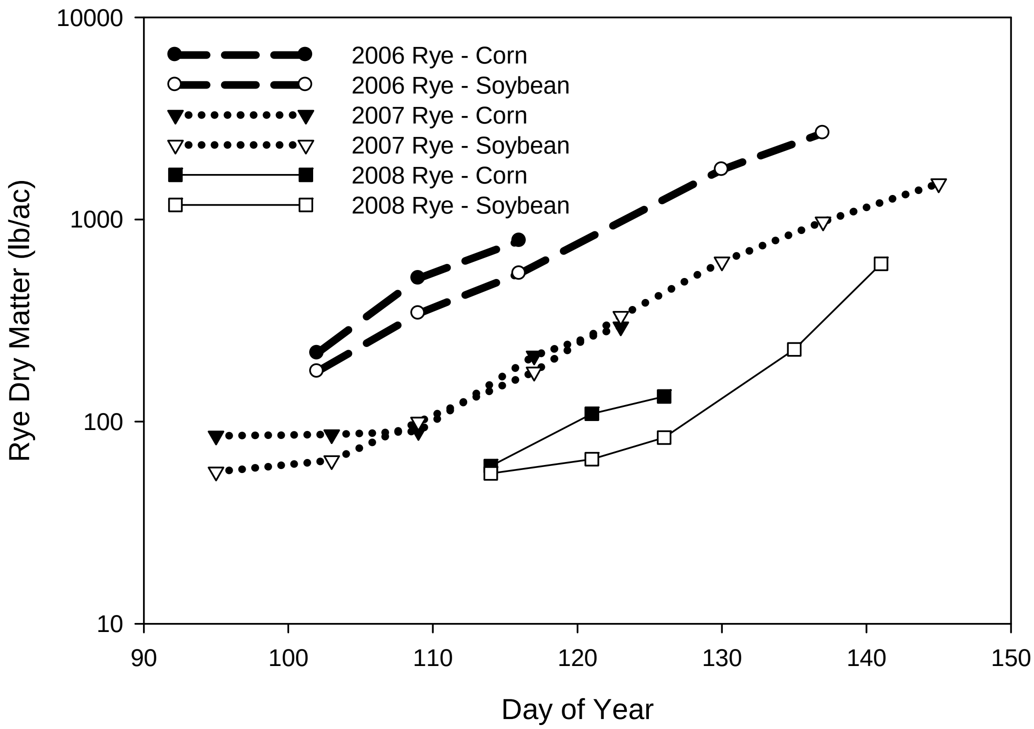

Figure 1. Rye dry matter produced as a cover crop for corn and soybeans.

Summary

Crop year 2005 could be considered a ‘calibration’ year for the new treatments imposed at the research site. So, it is difficult to draw broad conclusions from crop year 2005. However, of note is that in the 1st year of conversion from a row-crop system to a perennial system we have seen little if any reduction in nitrate-N concentration. Another important observation is that during April 2005 approximately 81% of the precipitation was intercepted by and exited via the subsurface drainage system.

The 2006 crop season was marked by typical early-season drainage patterns starting late-March as soils thawed. Drainage and precipitation were slightly above average in late March and April; each month had nearly one-half inch of precipitation greater than normal. Approximately eighty-three percent of April precipitation was intercepted by the drainage system. Excess precipitation basically ceased in early May as did all drainage. The remainder of the season had enough timely precipitation to produce adequate crop yield, but no subsurface drainage. March through November total was 8.59” below normal. Crop yield was very good considering the below normal precipitation experienced at the site. Nitrate-N concentrations the first year after perennial system establishment in 2005 dropped considerably; concentrations in the orchardgrass/clover system decreased by 33% from 14.7 to 9.7 mg/L, those in the kura system dropped from 13.1 to 6.9 mg/L. Of note for the rye cover crop system was that neither corn nor soybean grain yields were not adversely affected, even in a dry year, by the rye cover crop. Nitrate concentrations in subsurface drainage were not greatly reduced through the use of a cover crop.

January, February, April and May precipitation in 2007 was above normal. March was slightly below normal. As in 2006, June and July of 2007 were both well below normal, with August 8.62” above normal and September and October only slightly above normal. March through November total was 3.52” above normal. Average soil temperature at a 4”depth rose above freezing on March 13 and remained steady and began to rise after the 17th of March. All drainage ceased after the 1st week of June and commenced the third week of August after 10.5 inches was recorded in the preceding week. At least weekly samples were also available from the 3rd week of September until the end of October, a rather atypical drainage period. Average drainage for all treatments was 19.94 inches (5.5x the drainage of 2006 and 2.4x that of 2005). With 33.28” of precipitation between March 1 and November 30 and using an overall drainage volume of 20.38”, approximately 61% of the precipitation became subsurface drainage

As opposed to 2006, highest concentrations in 2007 were recorded for the 150 rate treatment within the corn year (concentrations were highest in the soybean year in 2006 for the 150 rate) and as in 2006, lowest concentrations were recorded for the perennial systems, specifically the orchardgrass/clover treatment. No significant differences were noted when comparing the fall and spring applications to each other across rates or crops.

Losses in 2007 were the highest recorded since the initiation of this treatment phase in 2005. The increase in loss was due to large drainage volumes in 2007 compared to previous years. Average drainage volume was 2.3 times that recorded in 2005 (5.5 times that in 2006).

Below normal precipitation in June and July quite likely diminished corn and soybean yields in 2007. Highest corn yield was for the Fall 125 N treatment. The rye cover crop system showed a decrease in corn yield of 7 bu/acre compared to no cover crop. This could again be the result of below normal precipitation in June and July (~5” below normal from Mar-Jul). Soybean yield ranged from 25-37 bu/acre. Rye in soybean lowered yield by 8 bu/ac compared to the spring 125 treatment. Rye biomass was much lower (~63% less in corn and ~57% less in soy) in 2007 compared to 2006. The decrease was quite likely due to a major growth setback as a result of very cold temperatures on April 12.

Overall, 2008 received about one inch more rain than a “normal” year, however the rainfall pattern was different with May and June being the two highest rainfall months. There were issues all over the state getting crops in the ground in 2008 due to this early rain. July, August and September were all below normal, but still fairly substantial with 4.12, 3.16 and 2.55 inches of rainfall, respectively. Drainage lagged behind rainfall enough for a large storm at the end of May to begin draining in early June causing drainage values to spike up over 9 inches for the month. After the rain lag from July to September, October picked up again with just under 4 inches. This coupled with relatively low temperatures delayed harvest as the fields would not dry out. Overall, drainage values were proportional to rainfall with 59% of the rain falling on the site leaving through subsurface drainage.

Just like in 2007, highest concentrations in 2008 were recorded for the 150 rate treatment (treatment 9); however, 2008 was a soybean year as opposed to corn in 2007 and lowest were found in the perennial systems, specifically the orchardgrass/clover treatment (treatment 18). No significant differences were noted when comparing the fall and spring applications to each other across rates or crops. Use of the LCD applicator compared to a conventional knife also showed no significant differences in resulting concentrations. Treatment 14 (rye cover crop treatment with corn) was only significantly lower than the comparable fall applied 125 lb/acre treatment but other comparable treatments (treatments 8, 12, 16) were not significantly different. Treatment 13, cover crop in soybeans for 2008 was not significantly different than any comparable treatments (treatments 3, 7, 11, 15). The strip tillage system in either crop did not exhibit any significantly different effects on NO_3-N concentrations. Significance was noted when comparing the N rate treatments. Treatment 9, which was planted with soybeans in 2008 and received 150 lb/acre N in 2007, had the highest nitrate concentrations of all treatments.

Corn yield values were the highest recorded since 2005, the initial "calibration" year. The highest observed corn yield was for the Spring 150 lb/acre N treatment, which also corresponds to the highest LSNT results. It was closely followed by LCD 125 lb/acre N and Fall 125 treatments. The rye cover crop system showed an increase, although not significant, in corn yield of 7 bu/acre compared to no cover crop. Soybean yield ranged from 39-49 bu/acre. Rye in soybean lowered yield by 4 bu/ac compared to the Spring 125 treatment.

Pekin Project Site

Drainage management practices are being evaluated at the Pekin school drainage facility. There are a total of nine plots at this facility. Three different management practices are being utilized and evaluated. The treatments include the following:

- 3 – plots with conventional drainage (drain tile at 3.5-4 ft deep).
- 3 – plots with controlled conventional drainage with free flow in the spring (April –May) and fall (September-October). The outlet control was set at 2 ft below the ground surface except during free flow.
- 3 – plots with pseudo-shallow drainage (control structure set at 2 ft below surface). This treatment would be used to represent a system similar to shallow drainage.

These three treatments are being evaluated to investigate the impacts of drainage management practices on drainage volume, nutrient concentrations in the subsurface drainage, and grain yield. Again, these factors will be evaluated over the five year term of this project. Since significant climate variability exists and the response of variable weather conditions on drainage management systems is needed it is important to evaluate the treatment response over the entire duration of the project phase. In addition to drainage management practices, drainage from two plots flows through a passive biofilter. One of the plots is a conventional drainage plot and one is a shallow drainage plot. The concentration of nutrients entering and exiting the biofilters is being monitored to document any reductions as a result of the passive biofilter.

Precipitation and Drainage

Crop years 2005 and 2006 were both unusually dry years at the Pekin site (Figure 2 and Figure 4). Precipitation recorded in 2007 was 10" above normal (Figure 6). On average, 842mm (33.15") of precipitation is recorded for the region (1971 to 2000). In 2005, 633 mm (24.93") were recorded at the site. Precipitation from mid-March through the end of 2005 was less than 18 inches (Figure 2) with only about 8 inches from mid-March through the end of June. In 2006, slightly less total precipitation was recorded. Only 580 mm (22.83") of precipitation was recorded for the year; less than 2/3 of normal amount (Figure 4). In 2007, 1100 mm (43.32") of precipitation was recorded (Figure 6). Precipitation in 2008 tracked along with the historic average quite well with the final amount of rain approximately 1” below normal. Drainage volumes were very similar for both 2005 and 2006. There was on average slightly less than 4 inches of drain flow from the conventional drainage plots and less than 2 inches of flow from the pseudo-shallow drainage plots (Figure 3 and Figure 5). It is likely that there is some lateral seepage from the pseudo-shallow drainage and controlled drainage plots to the conventional drainage plots (See Figure 2 through Figure 5 below). The plan is to investigate this through additional water table monitoring during periods of high water tables and low evapotranspiration. In 2007 with the above normal precipitation, 42% of precipitation became conventional subsurface drainage. The controlled drainage system drainage volume was reduced by more than one half to 19% of all precipitation. The shallow drainage system yielded only 12% of the annual precipitation. Respectively, drainage volumes were 18.7, 8.6 and 5.2 inches for each of the three systems (Figure 7). In 2008 with the approximately average precipitation, 48% of precipitation became conventional subsurface drainage. The controlled drainage system drainage volume was reduced to 18% of precipitation. The shallow drainage system yielded substantially less with 10% of precipitation. Respectively, drainage volumes were 16.6, 6.2, and 3.3 inches for each of the three systems (Figure 9). Dates for drainage control are listed in Table 16, dates reflect when the controlled drainage fields were lowered to 48” below the ground surface. During all other dates the control structures were set to keep water level at 24” below ground surface.

Table 16. Dates that the controlled drainage fields were drained down to 48" below the ground surface.

	Structure opened and fields drained for:	
	Field work (48”)	Harvest (48”)
2005	4-14 to 6-14	9-8 to 11-17
2006	3-31 to 6-1	9-28 to 11-7
2007	4-3 to 5-31	9-27 to 11-6
2008	4-14 to 5-29	9-12 to 11-12

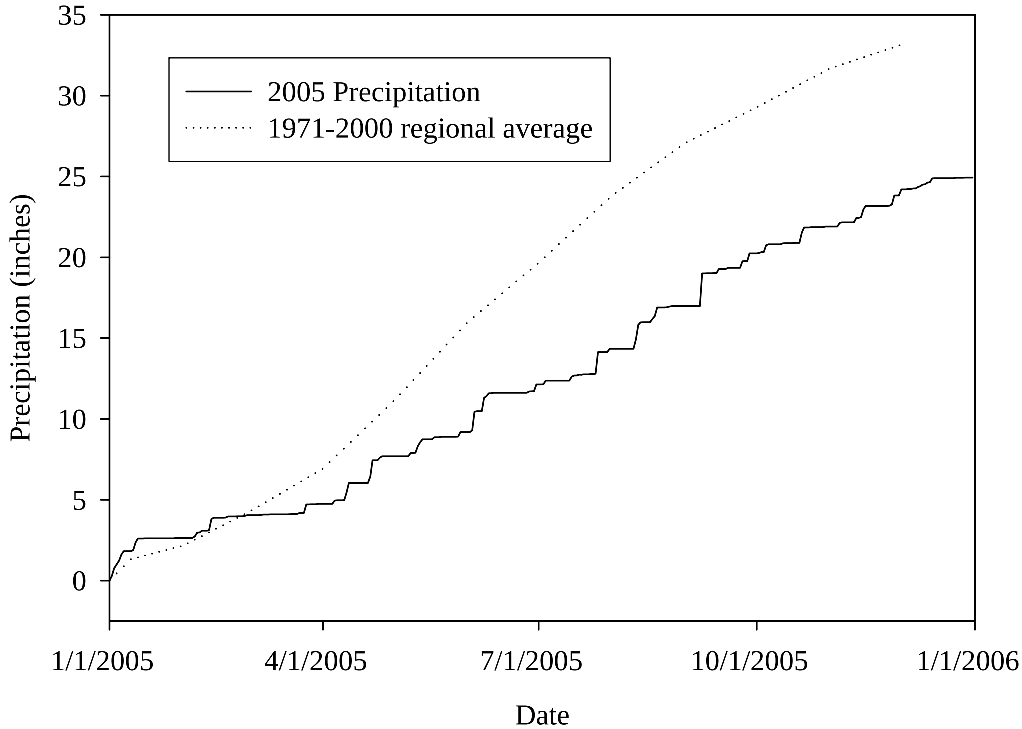

Figure 2. Precipitation in 2005 compared to the 30-year regional average.

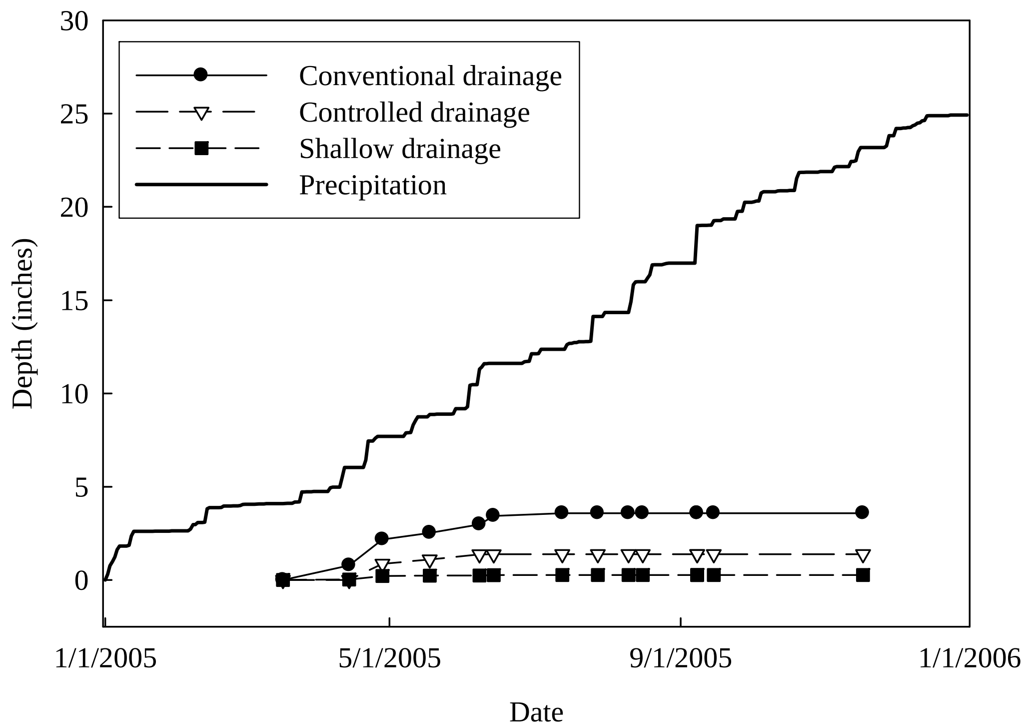

Figure 3. Precipitation and subsurface drainage at the Pekin site in 2005 during monitoring period.

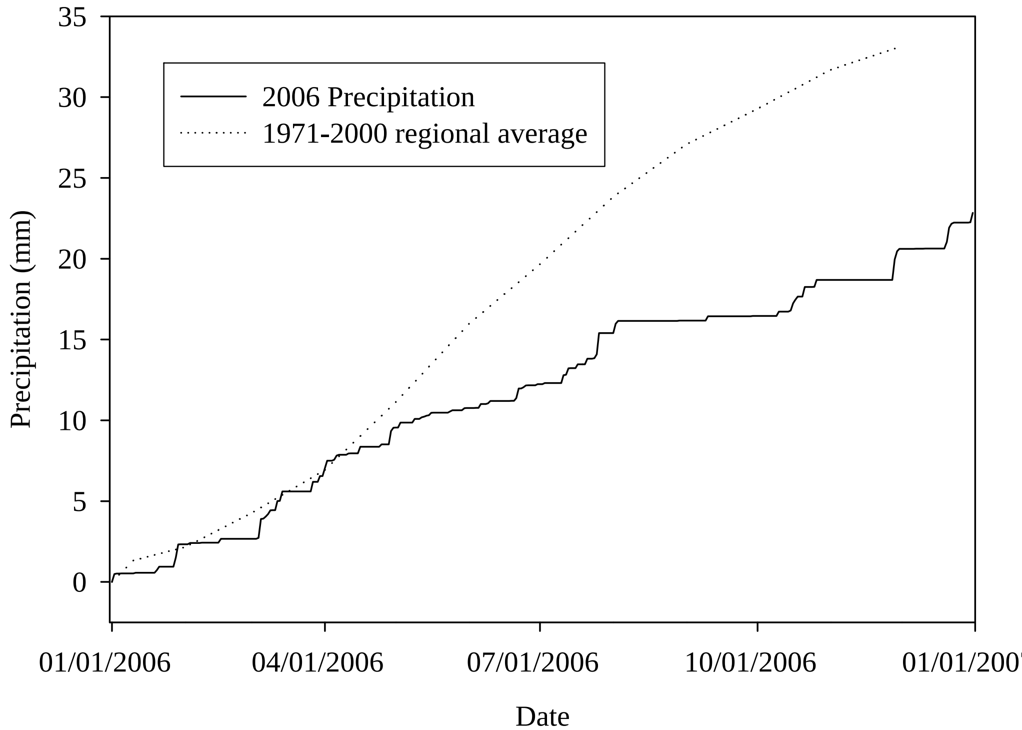

Figure 4. Precipitation in 2006 compared to the 30-year regional average.

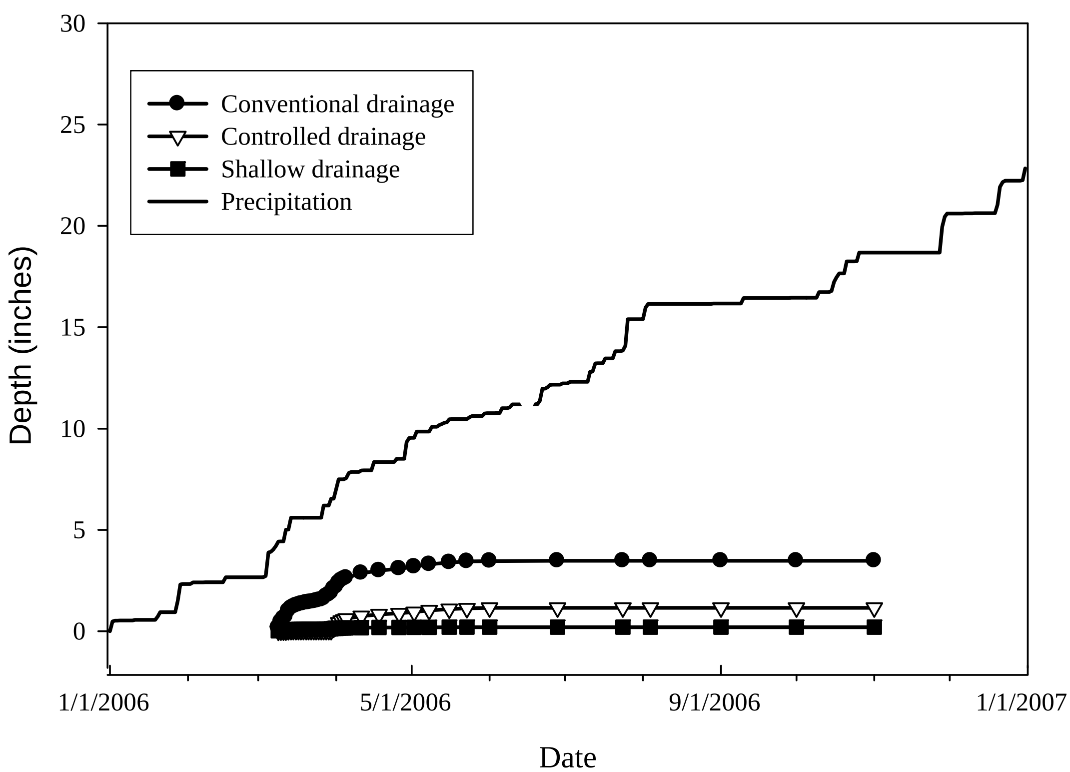

Figure 5. Precipitation and subsurface drainage at the Pekin site in 2006 during the monitoring period.

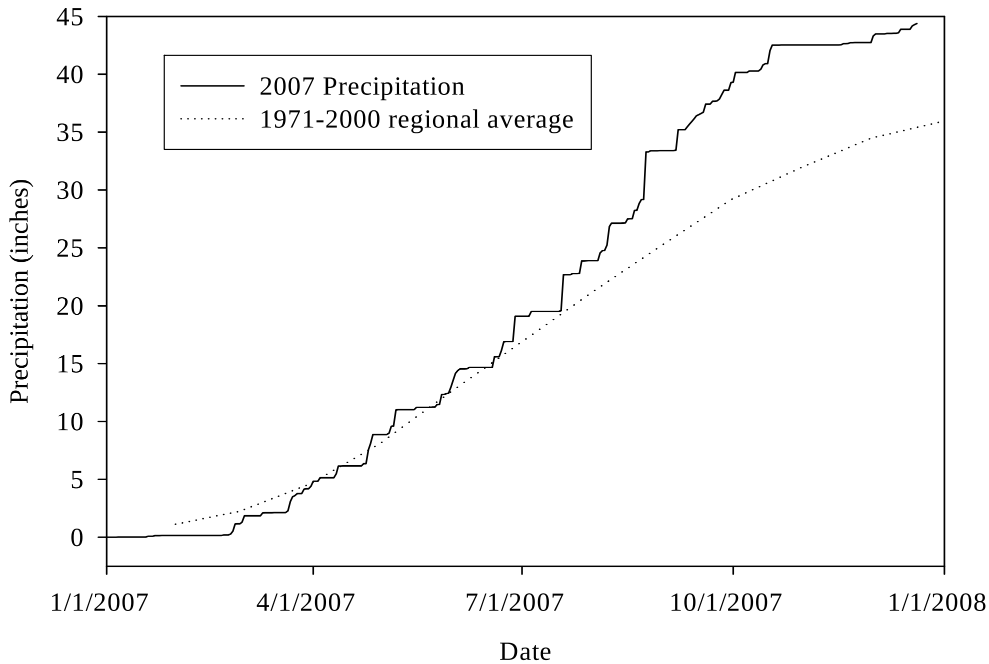

Figure 6. Precipitation in 2007 compared to the 30-year regional average.

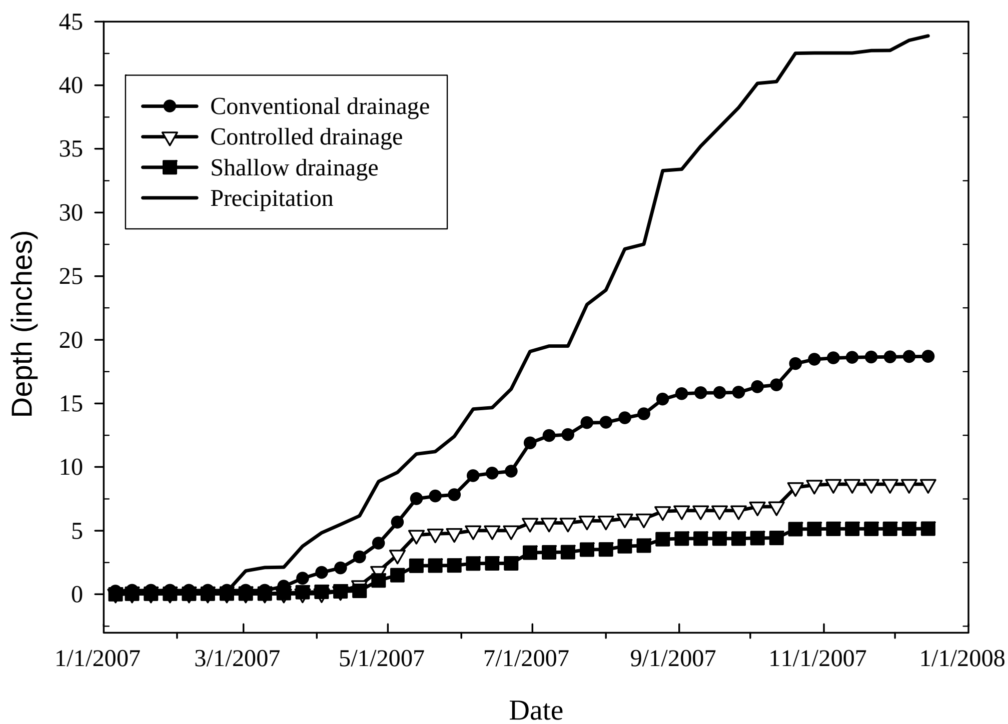

Figure 7. Precipitation and subsurface drainage at the Pekin site in 2007 during the monitoring period.

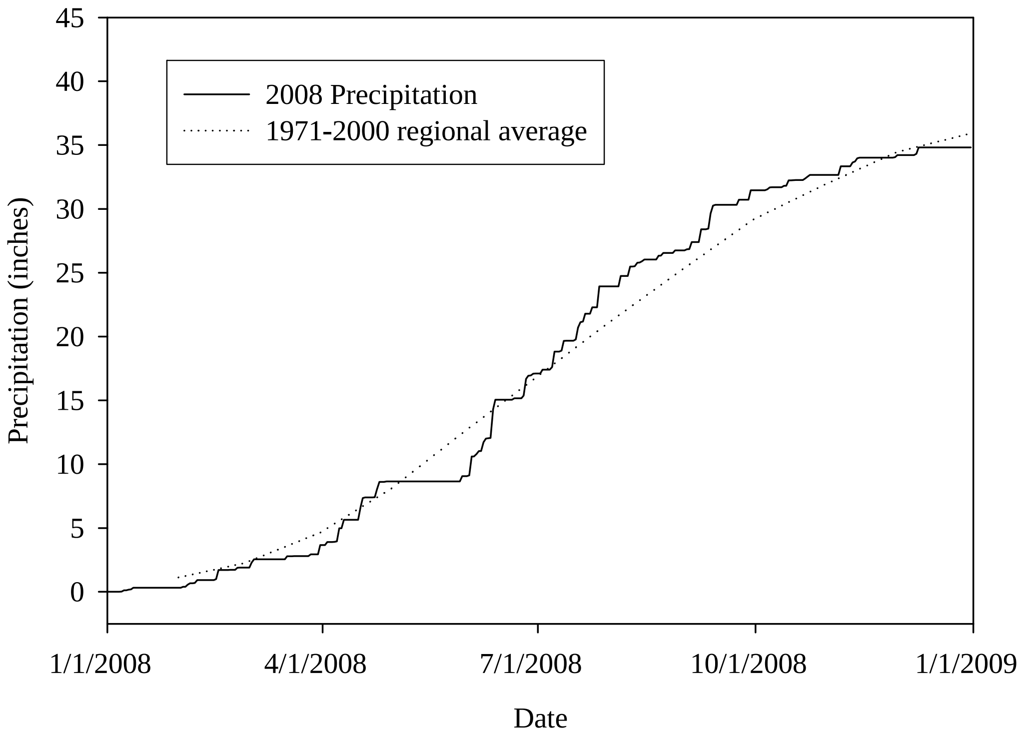

Figure 8. Precipitation in 2008 compared to the 30-year regional average.

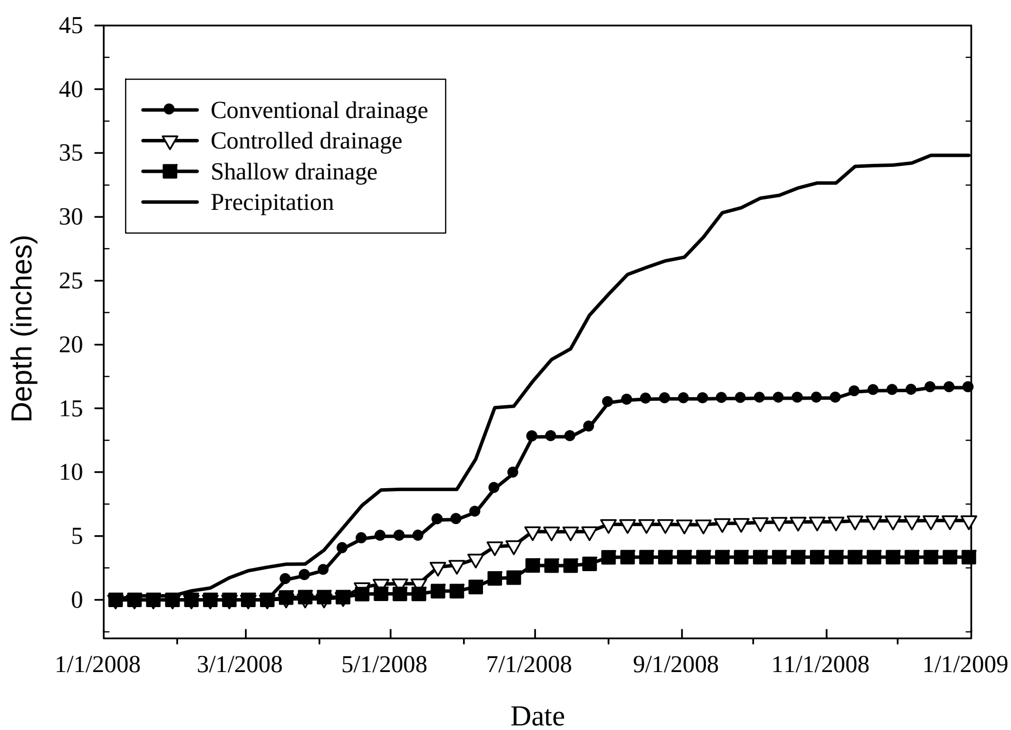

Figure 9. Precipitation and subsurface drainage at the Pekin site in 2008 during the monitoring period.

Corn and Soybean Yields
Historically, corn yields have been relatively low, when compared to state and county averages. The 2006 growing season was plagued with planting and fertilizing issues that resulted in meaningless yield data, and is not included here. Low yields in 2005 and 2007 are not, however, due to drainage management schemes as yields are very similar between treatments (Figure 10). The 2008 growing year produced a very nice crop with yield increases over 2007 between 80 and 90 bushel/acre.

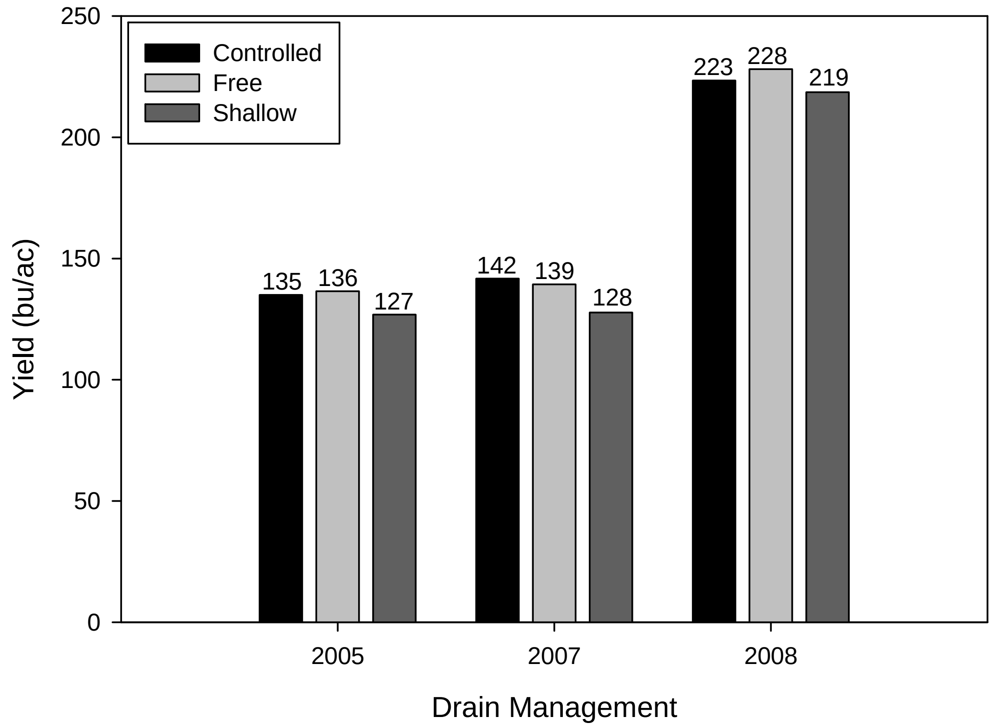

Figure 10. Corn yields at the Pekin site.

Soybean yields (Figure 11) have been steady with a slight increase in 2007. In 2005, a dry year, lower yields are observed on the free drainage and the shallow drainage treatments. The 2006 soybean growing season was also plagued by planting and fertilization issues, and the data is not included here. There is a slight decrease in yields in the free drainage treatment over all years when compared to the controlled drainage and shallow drainage treatments; however, the decrease is slight. Since there is not a strong trend in yields with treatment, the only factor to compare between treatments is nitrate concentrations observed in the drain water.

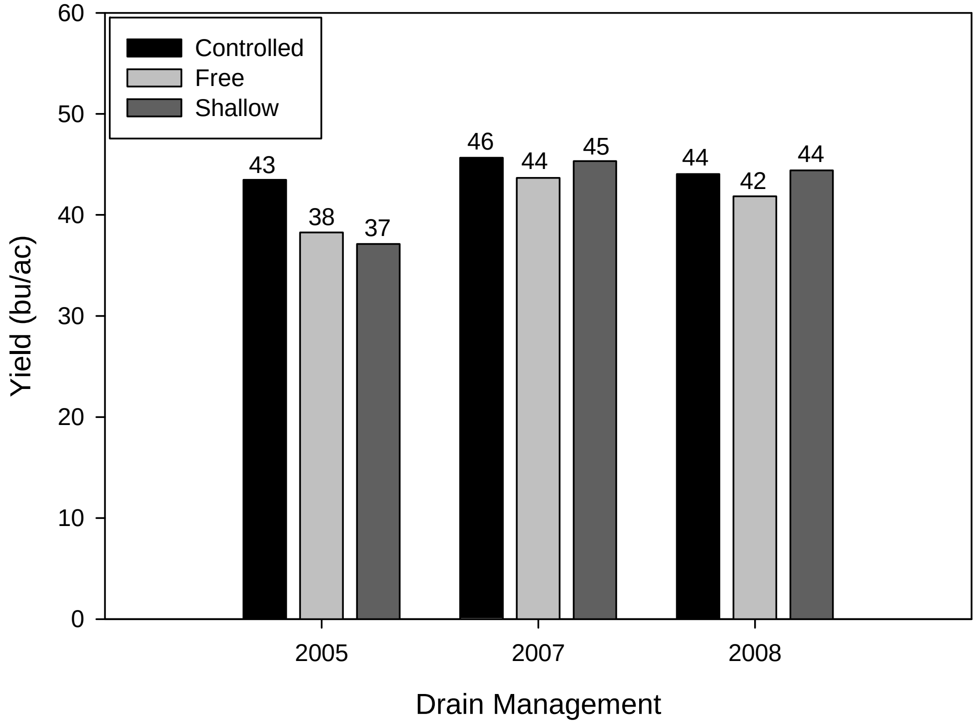

Figure 11. Soybean yields at the Pekin site.

Nitrate-Nitrogen Concentrations
Water samples to determine nitrate-nitrogen (NO_3-N) concentration were only available in April and May, in 2005-06, due to low flow conditions encountered. In 2007, water samples were available in late March, April, May, June, July, August and early September before drainage ceased. Sampling in 2008 was similar to 2007. Listed in Table 17 are flow-weighted NO_3-N concentrations for all treatments determined by summing individual loadings through the season and dividing it by the total drainage, thereby weighting the final value to reflect a specific drainage periods influence on the overall value. Values between treatments during individual years were very similar. When comparing years, values were much higher in 2007. The use of a wood-based boireactor constructed at the time of subsurface drain installation and consisting of wood chips surrounding the drain line decreased the concentrations being released from the standard installation, conventional drainage treatment (Figure 12, Figure 13, Figure 14, and Figure 15). Results from the bioreactor collecting drainage from the shallow management scheme are presented in Figure 16, and Figure 17. Due to minimal drainage volumes, and few corresponding samples, in 2006, data for the shallow drainage bio-filter is not included. Removals are noticed in the majority of samples taken after each bioreactor.

Table 17. Flow-weighted nitrate concentration for all treatments (mg/L).

	Conventional		**Controlled**		**Shallow**	
	Average	Std. Dev.	**Average**	Std. Dev.	**Average**	Std. Dev.
2005	6.71	1.16	6.40	2.14	4.57	2.49
2006	6.92	0.59	7.20	1.44	6.72	1.86
2007	10.69	1.98	12.08	2.75	12.88	1.63
2008	6.23	2.97	5.17	3.32	5.95	2.05

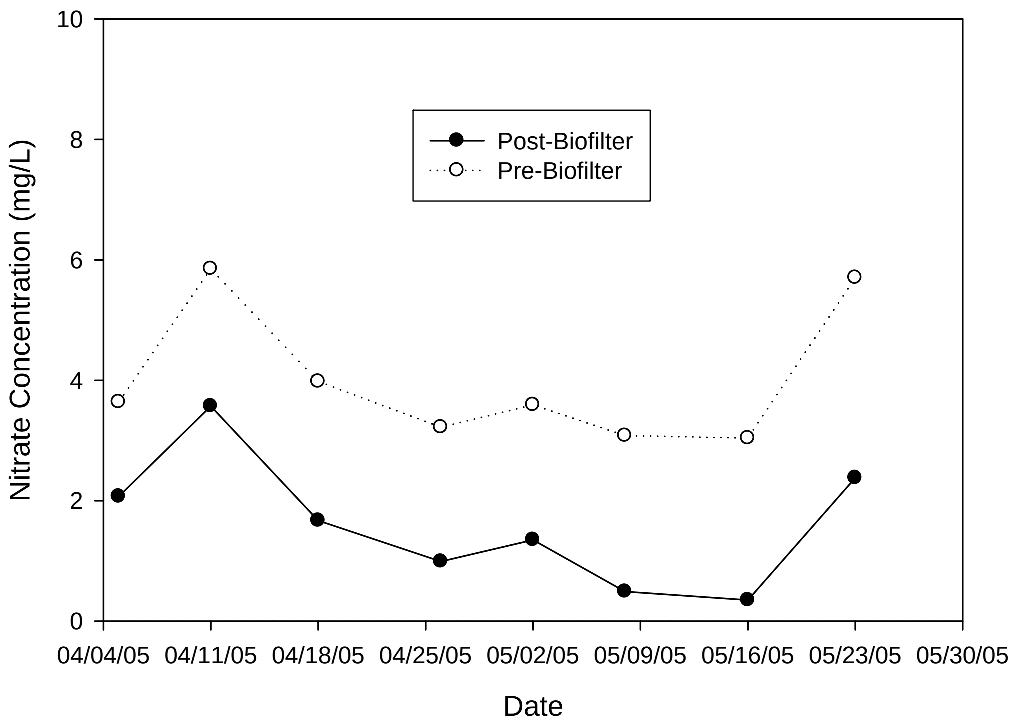

Figure 12. 2005 Conventional drainage bio-filter nitrate data.

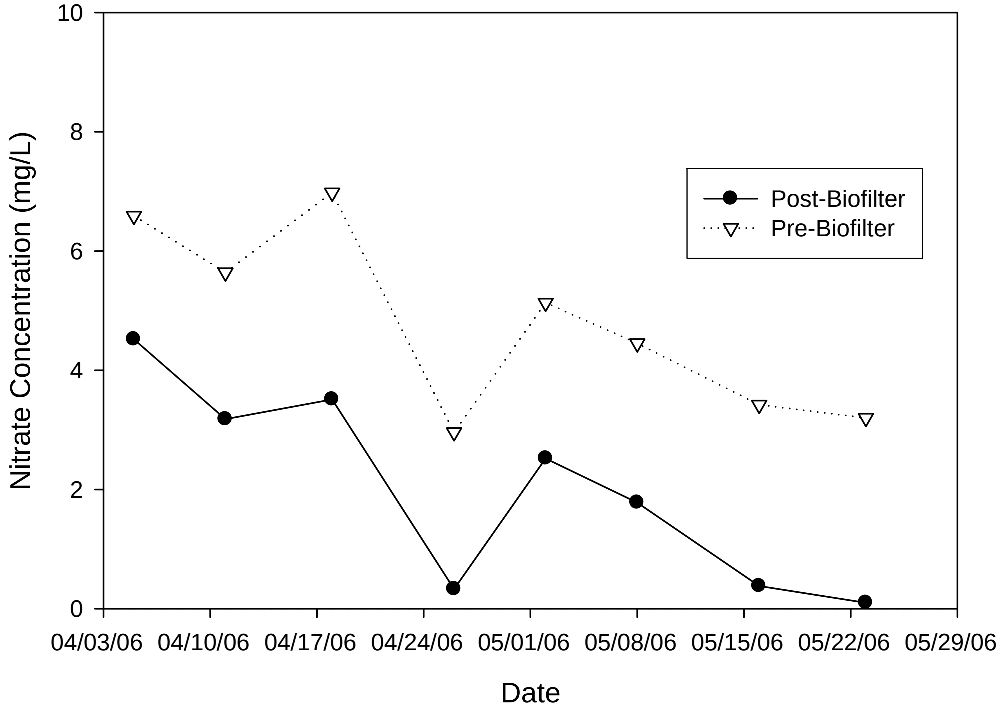

Figure 13. 2006 Conventional drainage bio-filter nitrate data.

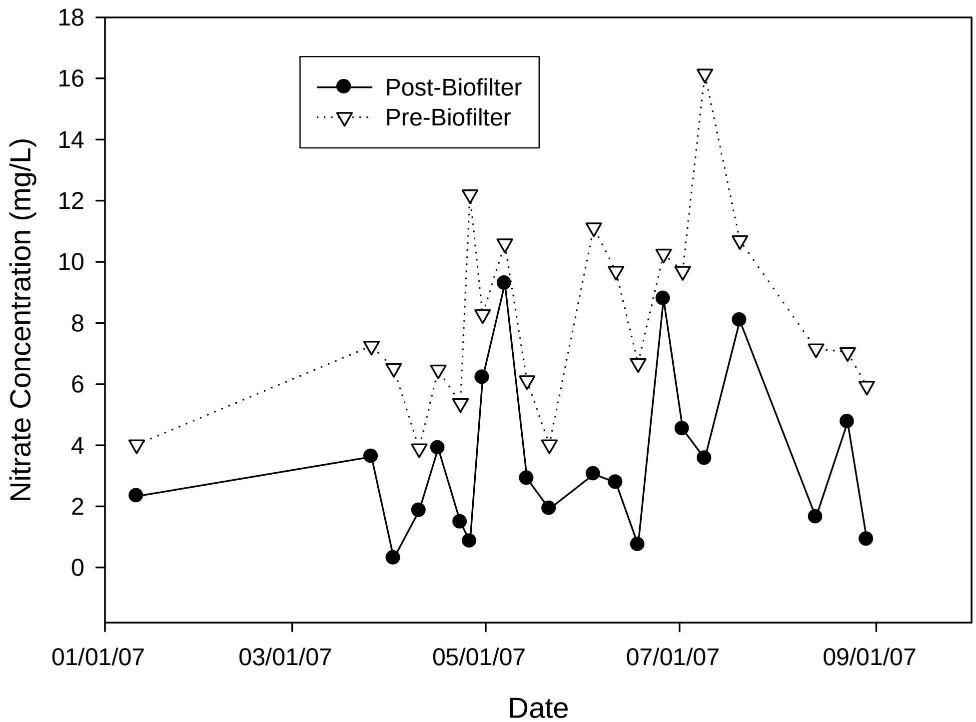

Figure 14. 2007 Conventional drainage bio-filter nitrate data.

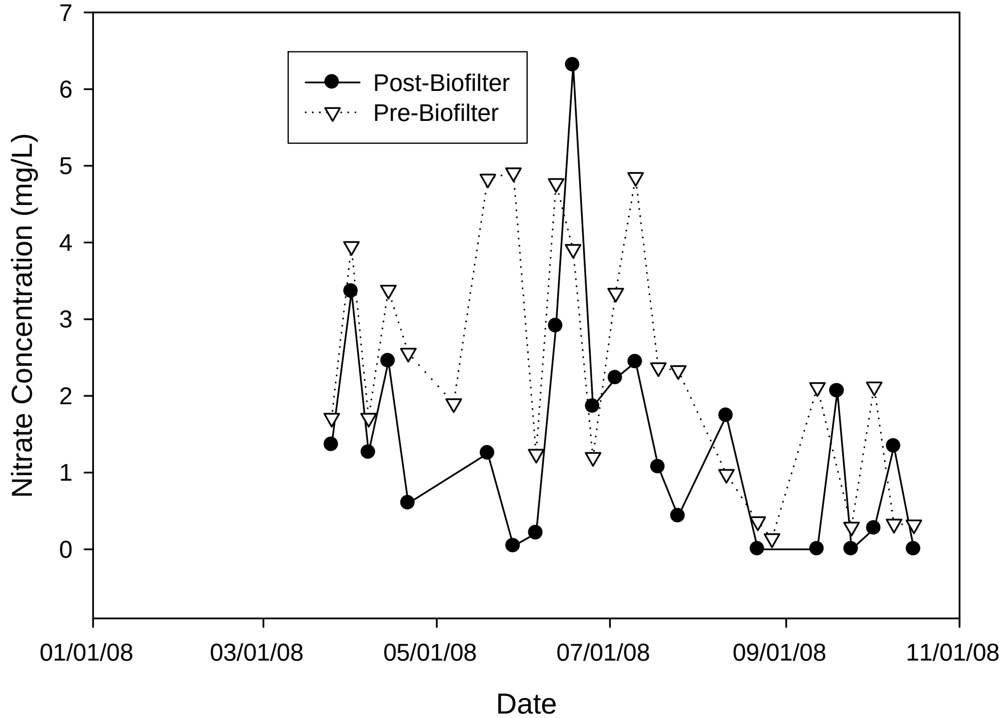

Figure 15. 2008 Conventional drainage bio-filter nitrate data.

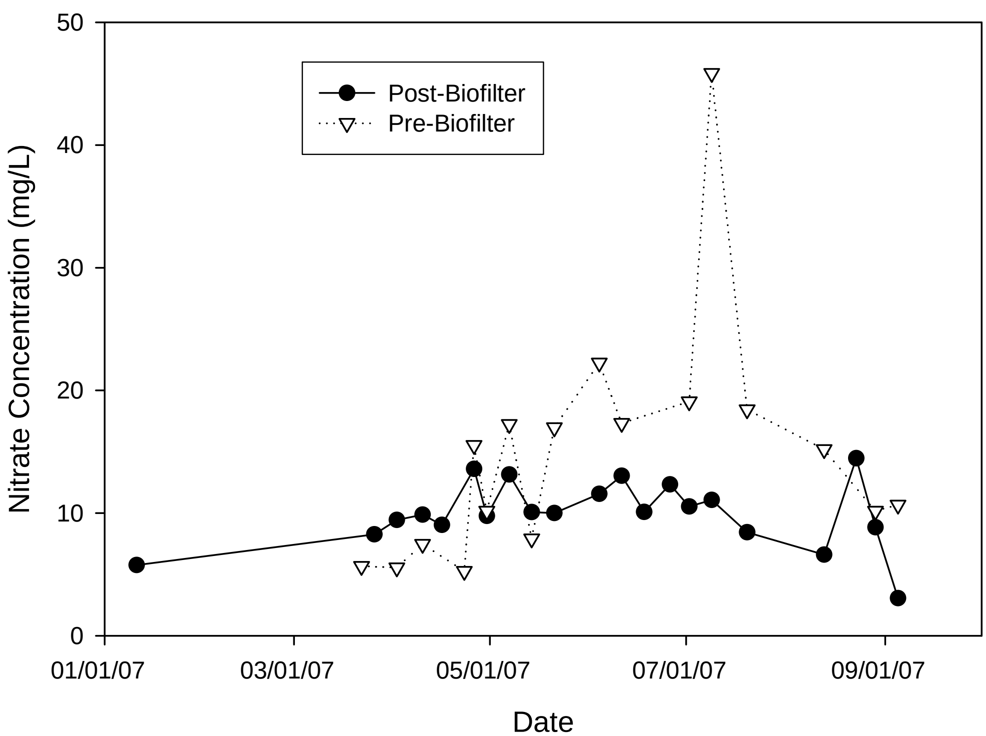

Figure 16. 2007 Shallow drainage bio-filter nitrate data.

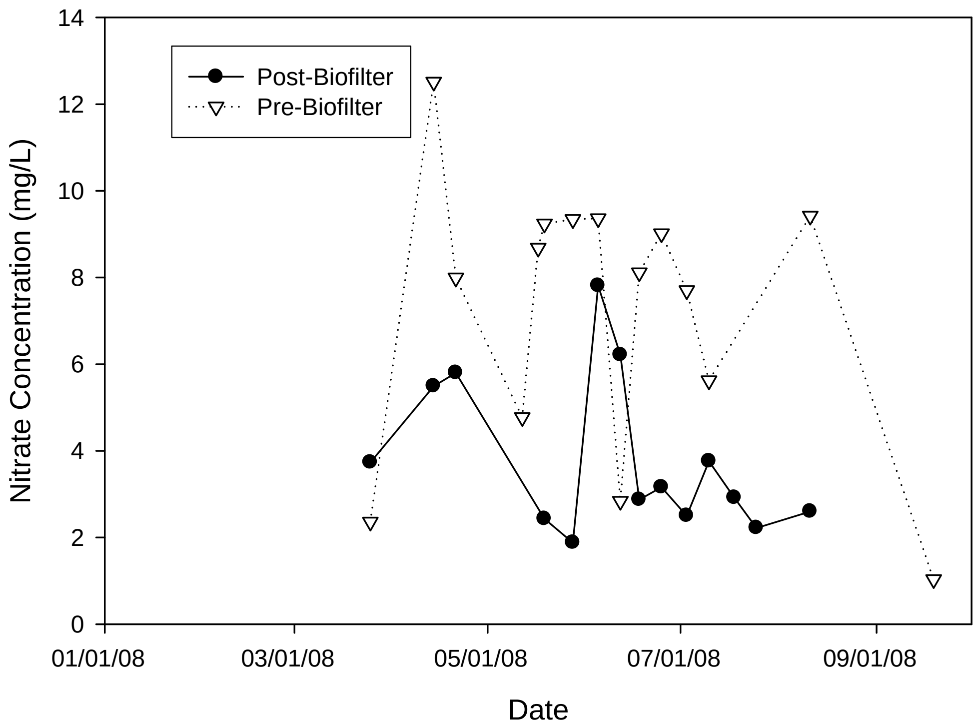

Figure 17. 2008 Shallow drainage bio-filter nitrate data.

Additional Water Quality Testing

While tiles were flowing in 2006, three sets of grab samples were collected over a four- week period from the conventional drainage biofilter plot and analyzed for the presence of additional contaminants that might be present. The results are presented in Table 18. Two useful measures of water quality are biological oxygen demand (BOD) and chemical oxygen demand (COD). They help measure the oxygen-depletion effect of a waste contaminant. The BOD test measures the oxygen demand of biodegradable pollutants whereas the COD test measures the oxygen demand of biodegradable pollutants plus the oxygen demand of non-biodegradable, oxidizable pollutants. COD is expressed as the mass of oxygen consumed per liter of solution. Biological oxygen demand (BOD) or biochemical oxygen is the amount of oxygen required by aerobic microorganisms to decompose the organic matter in a sample of water and used as a measure of the degree of water pollution. Ammonia, sulfate and chloride testing are also good indicators of water quality and were tested for in some of the samples. Ammonia is usually not found in large quantities in tile drainage because in the presence of oxygen rich water it will convert to nitrate. High levels of sulfate or chloride may be indicative of sewage contamination. None of the analytes were found to exceed water quality effluent or MCL standards. Additional testing in the future to detect any trends that may exist is needed.

Table 18. Additional analytical measurements performed on the 2006 conventional drainage biofilter plot.

Sampling Date Location	BOD	COD	Sulfate as SO_4	Ammonia as N	Chloride as Cl
	--- mg/L as O_2 ---		-------- mg/L --------		
4/18/2006					
pre-biofilter	<0.1	24.7	not tested		
post-biofilter	<0.1	45.7			
5/3/2006					
pre-biofilter	0.9	27.5	16.14	0.04	not tested
post-biofilter	1.6	46.2	18.08	0.11	
5/16/2006					
pre-biofilter	0.3	52.5	not tested	0.01	41.18
post-biofilter	0.6	62.7		0.10	34.74

Wetlands Monitoring and Evaluation

A unique aspect of the Iowa CREP is that nitrate reduction is not simply assumed based on wetland acres enrolled, but is calculated based on the measured performance of CREP wetlands. As an integral part of the Iowa CREP, a representative subset of wetlands (Figure 18) is monitored and mass balance analyses performed to document nitrate reduction. In addition to documenting wetland performance, this will allow continued refinement of modeling and analytical tools used in site selection, design, and management of CREP wetlands.

During 2008, eight wetlands were monitored for the Iowa CREP. These include BG, HS (north wetland), DJ, AL, RR, KS, DS, and VH wetlands. Flow was measured and autosampler composited daily samples were collected at all of these wetlands except RR Wetland. Weekly grab samples were collected at all of the monitored wetlands during 2008.

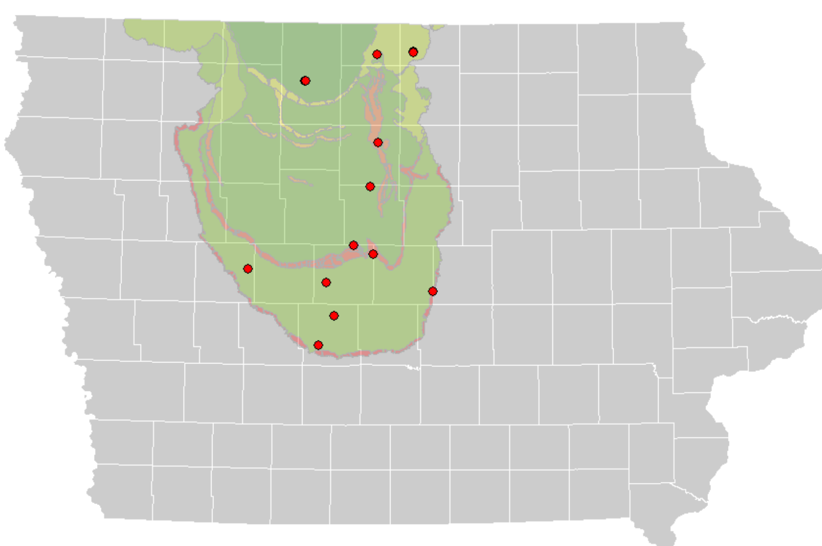

Figure 18. Wetlands monitored during 2004 to 2008.

For close interval monitoring of nitrate-nitrogen concentrations, wetlands were instrumented with automated samplers that collected daily composite water samples at wetland inflows and outflows. Grab samples were collected at an approximately weekly interval at inflow and outflow locations, and from within the wetland near the outflow location when there was no outflow. Selected wetland inflows and wetland outflows were instrumented with Doppler flow meters for continuous measurement of water depth and flow velocity. These were combined with channel profiles to calculate discharge. Wetland water levels were monitored continuously using stage recorders in order to calculate pool volume and discharge at outflow structures. Wetland water temperatures were recorded at five minute intervals for numerical modeling of nitrate loss rates.

By design, the wetlands selected for monitoring span the 0.5% - 2.0% wetland/watershed area ratio range approved for Iowa CREP wetlands. The wetlands also span a nearly five fold range in average inflow nitrate concentration (Table 19). The wetlands thus provide a broad spectrum of those factors most affecting wetland performance: hydraulic loading rate, residence time, nitrate concentration, and nitrate loading rate. Despite significant variation with respect to average nitrate concentrations and loading rates, the wetlands display similar seasonal patterns. Nitrate concentrations and mass loads are typically somewhat depressed during the winter, increase to their highest levels during high flow periods in spring and early summer, decline with declining flow in mid to late summer or fall, and may increase again if there is increased flow during late summer or fall. Winter wetland inflow concentrations are generally high, but somewhat lower than peak spring and summer concentrations (Figure 19). These nitrate concentration and flow patterns are representative of the patterns that are expected for future wetlands restored as part of the Iowa CREP.

Nitrate Loss from Wetlands

Mass balance analysis and modeling were used to calculate observed and predicted nitrate removal for wetlands where flow was measured. Inflow and outflow nitrate concentrations measured in wetlands are illustrated in Figure 19. In addition, Figure 19 shows the range of outflow concentrations predicted for these wetlands by mass balance modeling with water budget, temperature, and nitrate concentration inputs and forcing functions.

Several equipment malfunctions and extreme flooding events resulted in loss of daily inflow water samples during some peak flow events at BG, DJ, KS, and VH wetlands during 2008. Because daily inflow nitrate concentrations are critical during peak flow events when a substantial portion of the total annual load may be delivered to the wetland, missing inflow concentrations during peak flow events were estimated so that the observed outflow concentration fell within or near the modeled outflow concentration range for that day. This generally resulted in low estimated inflow concentrations on peak flow days which is consistent with the expected dilution of nitrate associated with overland flow.

Table 19. Wetland flow-weighted average (FWA) nitrate concentration and percent nitrate removal.

Wetland ID	Year	Inflow FWA Nitrate-N (mg/L)	Outflow FWA nitrate-N (mg/L)	Percent nitrate removal
AL	2007	13.36	7.82	43.3
AL	2008	13.84	8.10	44.9
BG	2007	16.69	14.97	10.7
BG	2008	8.58	8.01	6.9
DJ	2007	10.50	8.59	19.8
DJ	2008	10.37	8.85	16.3
DS	2008	8.45	4.34	54.2
HM	2006	11.78	2.52	78.5
HS	2007	6.20	0.73	91.8
HS	2008	5.21	0.79	86.8
JR	2007	12.97	9.46	29.2
KS	2008	11.90	9.81	18.2
ND	2007	15.66	12.53	21.1
TI	2006	11.85	8.91	25.0
UML	2004	3.53	2.48	29.7
VH	2004	18.10	5.75	68.2
VH	2007	15.76	7.32	63.6
VH	2008	10.73	3.77	68.5

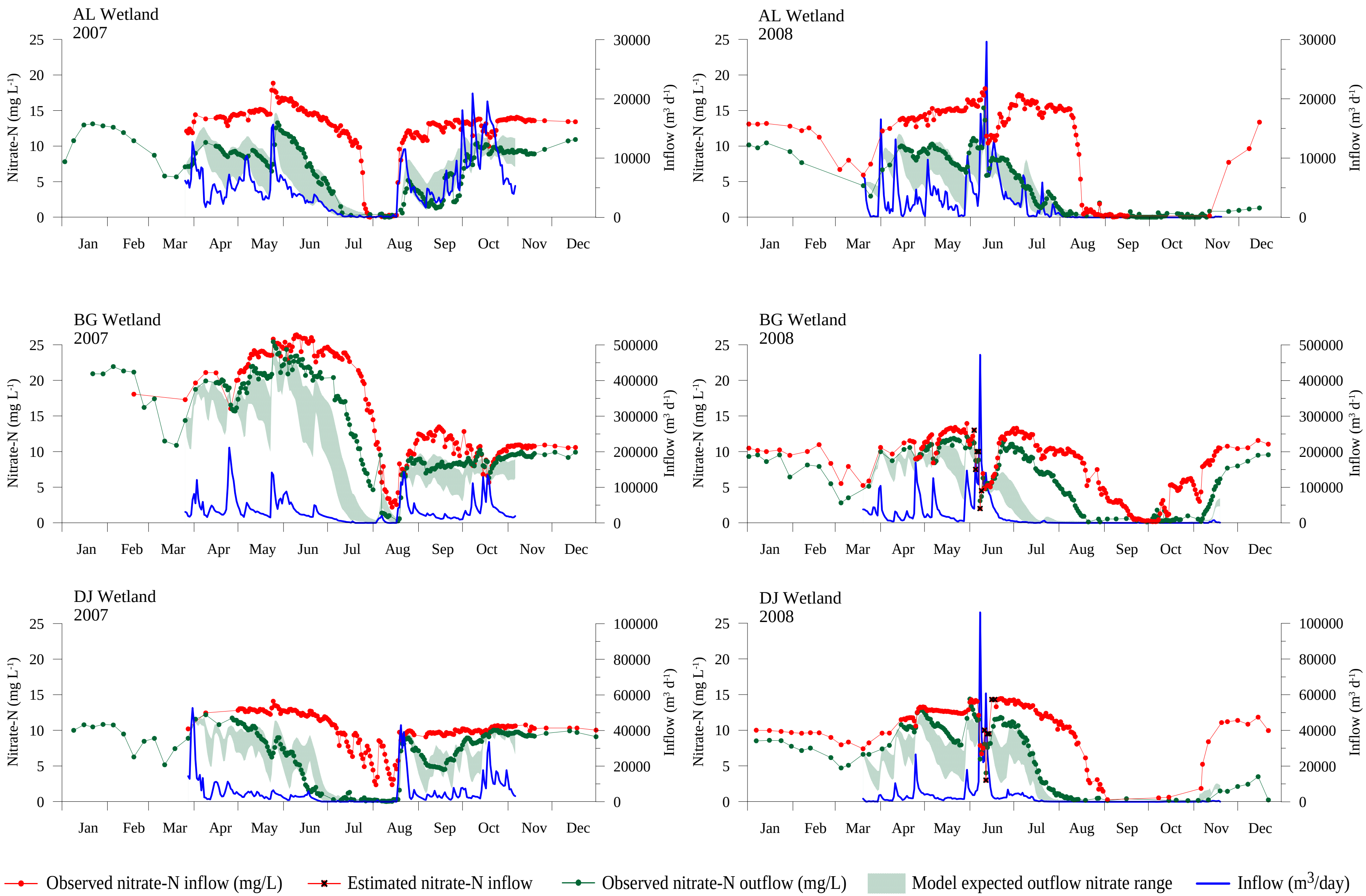

Figure 19. Measured and modeled nitrate concentrations and flows for selected wetlands monitored.

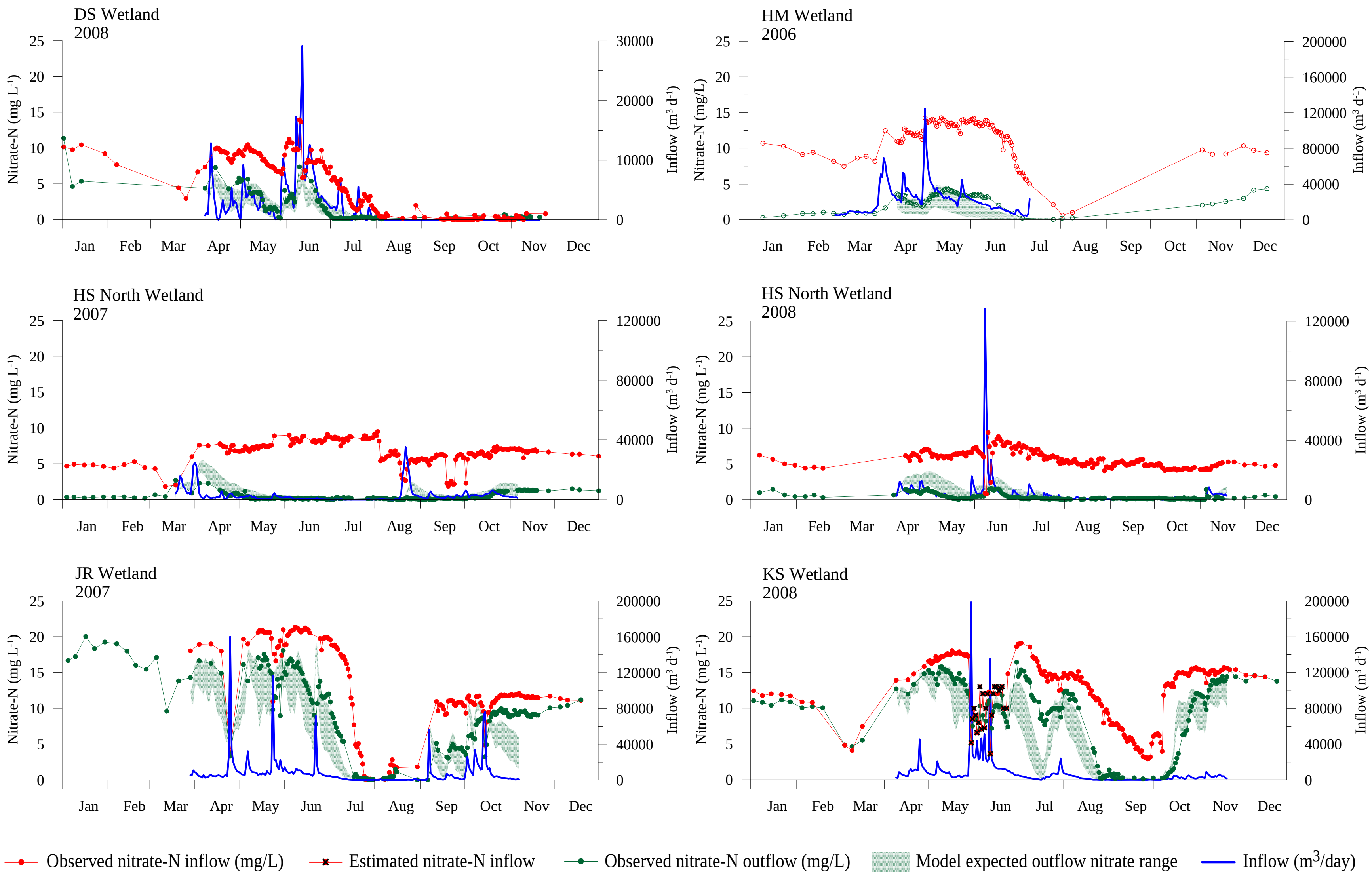

Figure 19 (continued). Measured and modeled nitrate concentrations and flows for selected wetlands monitored.

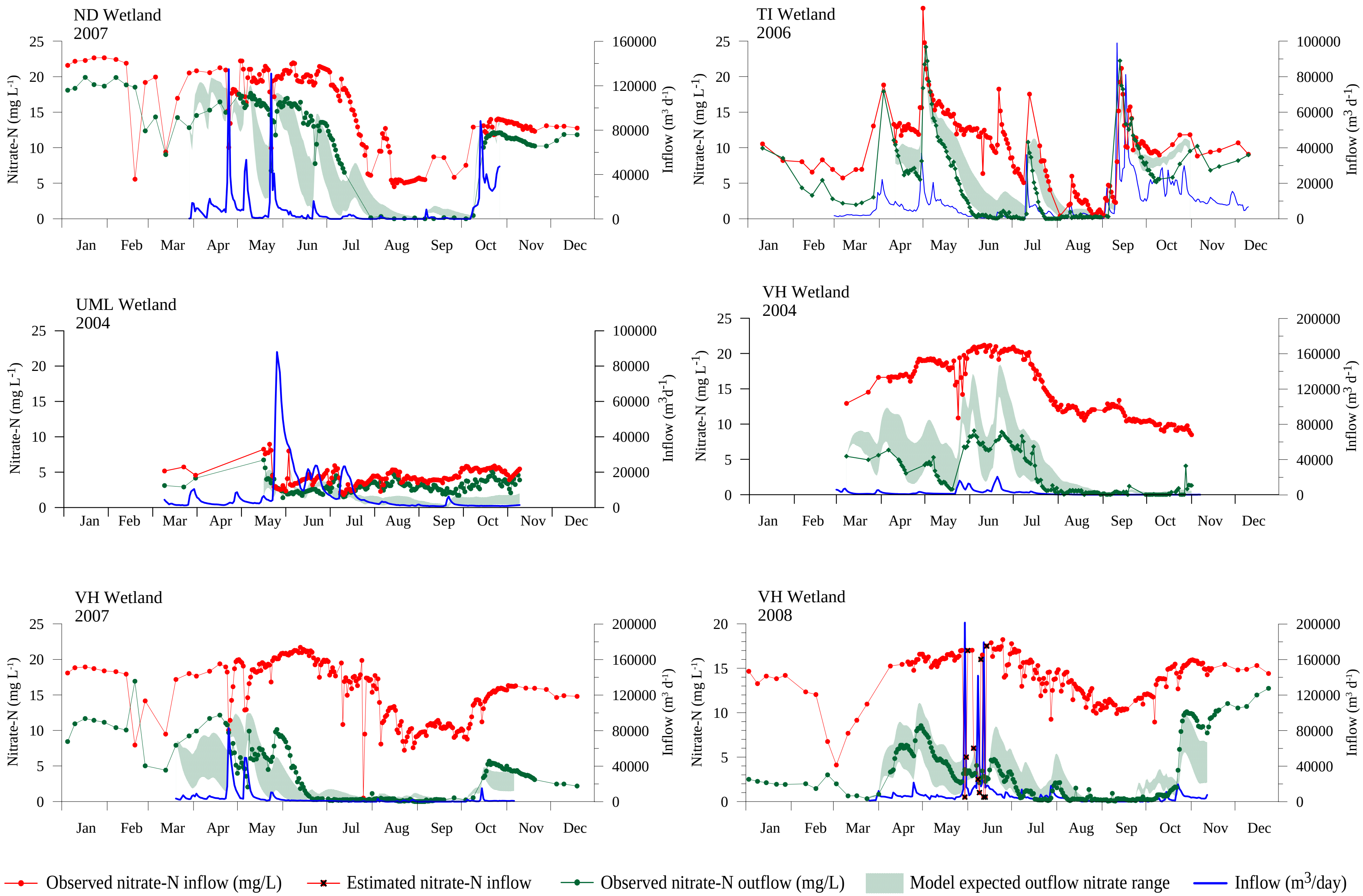

Figure 19 (continued). Measured and modeled nitrate concentrations and flows for selected wetlands monitored.

The monitored wetlands performed as expected with respect to nitrate removal efficiency (expressed as percent removal) and mass nitrate removal (expressed as Kg N ha^{-1} $year^{-1}$). Wetland performance is a function of hydraulic loading rate, hydraulic efficiency, nitrate concentration, temperature, and wetland condition. Of these, hydraulic loading rate and nitrate concentration are especially important for CREP wetlands. The range in hydraulic loading rates expected for CREP wetlands is significantly greater than would be expected based on just the four fold range in wetland/watershed area ratio approved for the Iowa CREP. In addition to spatial variation in precipitation (average precipitation declines from southeast to northwest across Iowa), there is tremendous annual variation in precipitation. The combined effect of these factors means that loading rates to CREP wetlands can be expected to vary by more than an order of magnitude, and will to a large extent determine nitrate loss rates for individual wetlands.

Mass balance modeling was used to estimate the variability in performance of CREP wetlands that would be expected due to spatial and temporal variability in temperature and precipitation patterns. The percent nitrate removal expected for CREP wetlands was estimated based on hindcast modeling over the 25 year period from 1980 through 2005 (Figure 20). For comparison, percent nitrate removal measured for wetlands monitored during 2004 to 2008 are also presented and illustrate reasonably good correspondence between observed and modeled performance. Due to factors including excess overland flow entering wetlands during a flood event, debris accumulation at outflow structures, and poor reconciliation of inflow and outflow measures, hydraulic loading rates could not be estimated with sufficient precision for several wetlands monitored during 2007 and 2008. Those wetlands for which the hydraulic loading rates could not be reliably determined were not included in Figure 19. Several of the 2007 and 2008 results show hydraulic loading rates greater than anticipated due to an unusually wet late summer and fall during 2007 and June of 2008. Percent nitrate removal is clearly a function of hydraulic loading rate (Figure 20).

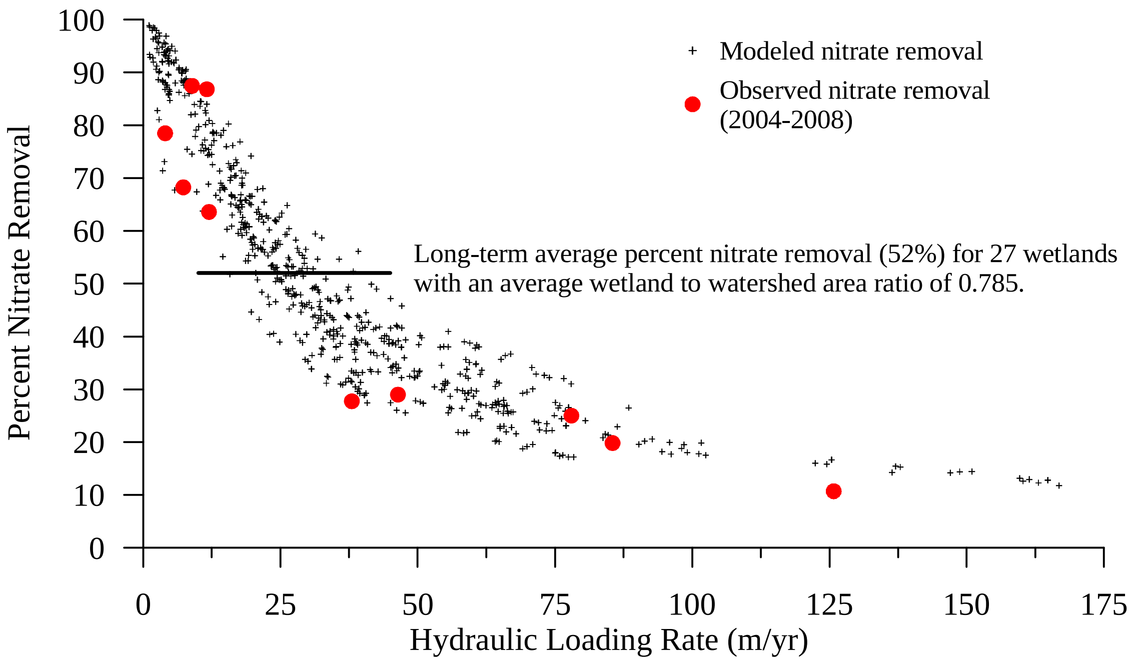

Figure 20. Modeled and observed nitrate removal efficiencies for CREP qualifying wetlands versus Hydraulic Loading Rate based on 1980 through 2005 input conditions.

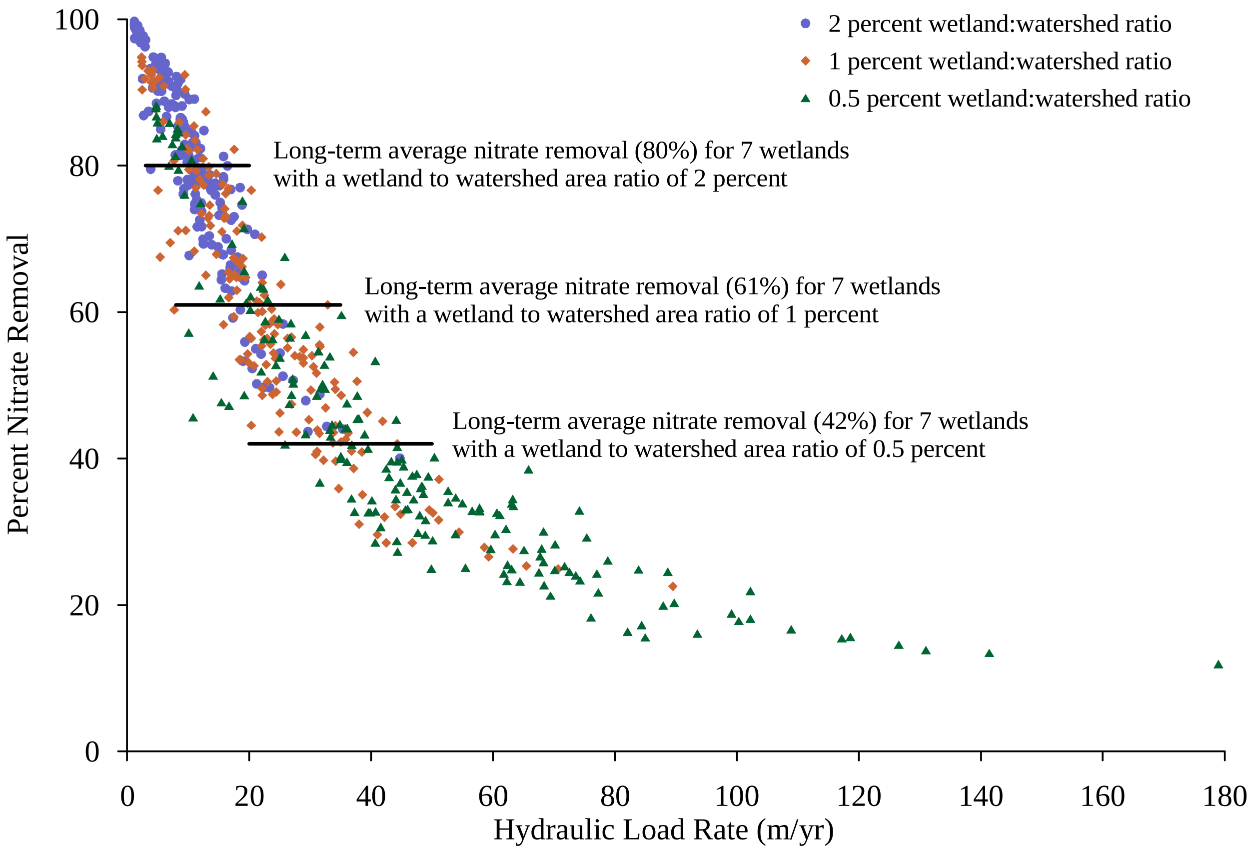

Figure 21. Modeled nitrate removal efficiencies for hypothetical wetlands evaluated at three wetland to watershed ratios, based on 1980 through 2005 input conditions.

Mass nitrate removal rates can vary considerably more than percent nitrate removal among wetlands receiving similar hydraulic loading rates. However, mass removal rates are predictable using models that integrate the effects of hydraulic loading rates, nitrate concentration, temperature, and wetland condition. Of particular interest in assessing the factors that affect potential long-term nitrate removal performance is evaluation of the role of wetland size in relation to the size of the encompassing watershed. Wetlands with relatively larger wetland to watershed ratios are expected to exhibit greater long-term nitrate removal performance than wetlands possessing lower ratios (0.5 to 2.0 percent representing the approved range of wetland to watershed area ratio for Iowa CREP wetlands). To evaluate the influence of wetland to watershed area ratio on long-term nitrate removal performance, we developed a set of 21 hydrological and nutrient mass balance simulation models for 7 hypothetical wetlands. Each wetland was evaluated with wetland to watershed area percentages of 2.0, 1.0, and 0.5. Inflow data were obtained from a set of 7 USGS stream gages, each representing inflow to a unique wetland, for the period of simulation spanning 1980 through 2005. Corresponding meteorological and temperature data were obtained from NWS weather stations nearest to the aforementioned stream gages. Each model was run with a constant inflow nitrate concentration equal to 14.3 mg NL^{-1}. Simulation results indicate that wetland to watershed ratio can exert profound influence on the expected long-term removal performance of constructed wetlands (Figure 21). Larger wetland to watershed ratios will promote significantly greater removal performance by reducing long-term hydraulic loading rates. Lower ratios, as illustrated in Figure

21, will produce significantly reduced removal performances and consistently higher hydraulic loading rates.

Crumpton et al. (2006) developed and applied a model that explicitly incorporates hydraulic loading rate, nitrate concentration, and temperature to predict performance of US Corn Belt wetlands receiving nonpoint source nitrate loads. This analysis included comparisons for 31 "wetland years" of available data (13 wetlands with 1-9 years of data each) for sites in Ohio, Illinois, and Iowa, including four IA CREP wetlands. The analysis demonstrated that the performance of wetlands representing a broad range of loading and loss rates can be reconciled by models explicitly incorporating hydraulic loading rates and nitrate concentrations (Crumpton et al., 2006). This model was updated to include the 2004 to 2008 Iowa CREP wetlands and exclude wetlands smaller than the 2.5 acre minimum size required by Iowa CREP criteria. The updated model (Figure 22) accounts for 88 percent of the observed variation in mass nitrate removed for the 33 wetland cases considered. The x-axis in Figure 22 is clipped to HLR <100 m/year, which excluded the 2007 BG wetland (HLR = 126 m/yr).

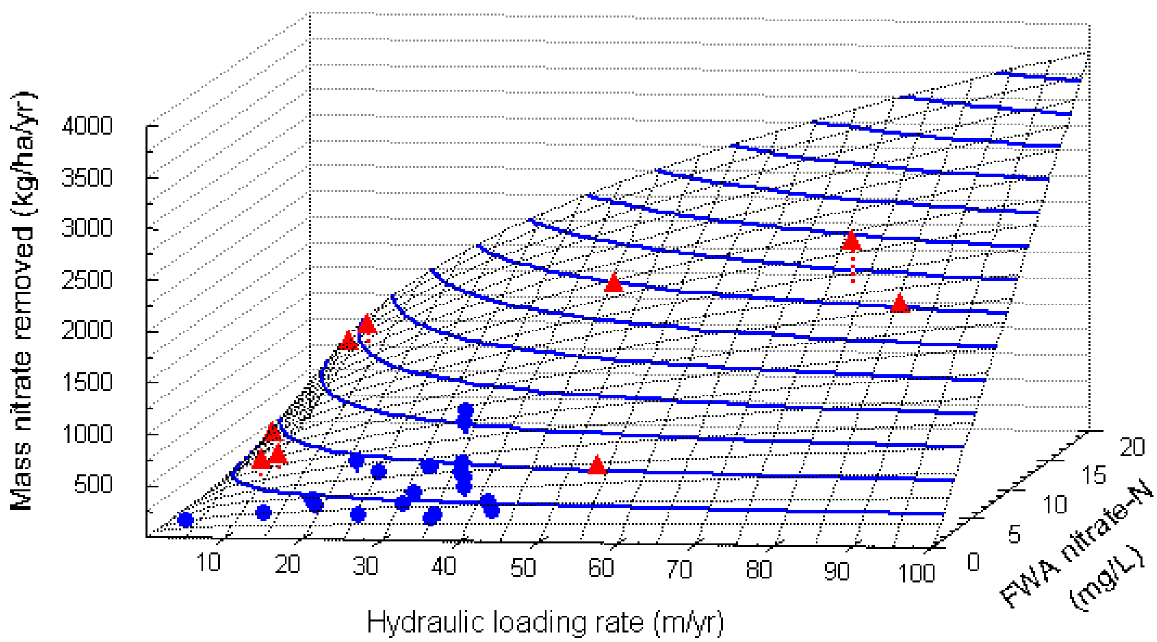

Figure 22. Observed nitrate mass removal includes Corn Belt wetlands representing 31 "wetland years" of data shown (adapted from Crumpton et al., (2006)). CREP and other Iowa wetland sites are shown as red triangles. Published results for Ohio and Illinois wetlands shown as blue circles.

References

Crumpton, W.G., G.A Stenback, B.A. Miller, and M.J. Helmers. 2006. Potential benefits of wetland filters for tile drainage systems: Impact on nitrate loads to Mississippi River subbasins. US Department of Agriculture, CSREES project completion report. Washington, D.C. USDA CSREES.

Outreach Activities Year 2005, 2006, 2007, and 2008

In addition to the evaluation that is taking place at the project sites in Gilmore City, Pekin, and the Wetlands sites, we have an active outreach program associated with this project. This includes presentations at technical and Extension related meetings, field days, the Drainage Research Forum, and Extension and scientific publications. The activities that are directly associated with the outreach component of this project in 2005, 2006, 2007, and 2008 are described below.

Events Organized

December 4, 2008 – Coordinated with Iowa Department of Agriculture and Land Stewardship and the Iowa Drainage District Association a Drainage Engineers Meeting in Fort Dodge, IA. There were approximately 15 attendees including drainage engineers from north central Iowa.

December 2, 2008 – Coordinated with Dr. Gary Sands from the University of Minnesota the 9th Annual IA-MN Drainage Research Forum in Owatonna, MN. There were approximately 95 attendees consisting of producers, contractors, and agency representatives from Iowa and Minnesota.

November 29, 2007 – Coordinated with Dr. Gary Sands from the University of Minnesota the 8th Annual IA-MN Drainage Research Forum in Ames, IA. There were approximately 75 attendees consisting of producers, contractors, and agency representatives from Iowa and Minnesota.

November 28, 2006 – Coordinated with Dr. Gary Sands from the University of Minnesota the 7th Annual IA-MN Drainage Research Forum in Owatonna, MN. There were approximately 85 attendees consisting of producers, contractors, and agency representatives from Iowa and Minnesota.

November 2, 2005 - Coordinated with Dr. Gary Sands from the University of Minnesota the 6th Annual IA-MN Drainage Research Forum held in Dows, IA. The forum was attended by 80 stakeholders that included individuals from both Iowa and Minnesota.

The Drainage Research Forum program focuses on drainage and water management issues including the implications of nitrogen management, water quality and drainage modeling at the watershed scale, preferential flow on drained lands, nitrate-removal wetlands, cropping strategies for nitrogen management and drainage water management. Presenters commonly include researchers from Iowa State University, University of Minnesota, and the USDA Agricultural Research Service.

Field Days

A field day was organized at the Gilmore City project site. The evening field day on August 18, 2008 was attended by approximately 80 stakeholders. The topics discussed were importance of science based policy information (Iowa Secretary of Agriculture Bill Northey), current crop issues (Paul Kassel and John Holmes), drainage district scale monitoring and nitrate-removal wetlands performance (Dr. William Crumpton), policy accomplishments at the research site and associated studies (Dean Lemke), highlights of what has been learned from 20 years of studies at

Gilmore City (Dr. Stewart Melvin and Dr. James Baker), and preliminary results of current treatments (Dr. Matt Helmers).

A field day was organized at the Gilmore City project site. The evening field day on June 30, 2005 was attended by approximately 75 stakeholders. The topics discussed were current crop issues (Paul Kassel), nitrate-removal wetlands (Dr. William Crumpton), the Targeted Watershed Grant (Dean Lemke and County Board of Supervisors), highlights from 15 years at Gilmore City (Dr. Stewart Melvin, Peter Lawlor, and Dr. James Baker), and controlled drainage (Matt Helmers).

Carl Pederson and Matt Helmers presented on drainage water quality and drainage water management at a field day at the Pekin project site on September 15, 2005. The "8 to 80 Water Quality Field Day" was attended by approximately 100 students from surrounding schools.

Oral Presentations at Extension Related Meetings

Extension Presentations (Iowa):

December 17, 2008 – Presentation on "Water quality update" at the Ag. Chemical Dealer Update in Ames, IA (85 attendees).

December 16, 2008 – Presentation on "Water quality and soil management – Ag. Drainage Well research results" at the Ag. Chemical Dealer Update in Storm Lake, IA (55 attendees).

December 10, 2008 – Presentation on "Effect of cover crops in reducing nitrate-nitrogen leaching in Iowa" at the Integrated Crop Management Conference in Ames, IA (120 attendees).

August 20, 2008 – Presentation on "Controlled drainage and nitrate-removal wetland performance" at NRCS Area 2 Technician Tour near Stanhope, IA (25 attendees).

August 6, 2008 – Presentation on "Controlled drainage and impacts of conservation practices on runoff" at the Iowa Learning Farm Field Day near Otho, IA (135 attendees).

June 26, 2008 – Presentation on "Controlled drainage water management" at a Drainage Field Day at the Southeast Research and Demonstration Farm near Crawfordsville, IA (50 attendees).

March 20, 2008 – Presentation on "Agricultural drainage water quality" at meeting organized by Humboldt USDA-NRCS (25 attendees).

February 29, 2008, March 7, 2008, and March 18, 2008 – Presentation on "Tile drainage and water quality" at Drainage Design Workshops held in Fairfield, Jefferson, and Rockwell City, IA (102 attendees).

February 29, 2008, March 7, 2008, and March 18, 2008 – Presentation on "Benefits of tiling" at Drainage Design Workshops held in Fairfield, Jefferson, and Rockwell City, IA (102 attendees).

February 28, 2008 – Presentation on "Drainage implications of continuous corn" to Hamilton County Ag. Series in Webster City, IA (15 attendees).

February 27, 2008 – Presentation on "The Iowa Plan for Wetland and Drainage Integrated Landscape Systems" at the 2008 Iowa Water Conference (125 attendees).

February 22, 2008 – Presentation on "Drainage research in Iowa" to members of the Iowa Corn Growers in Independence, IA.

January 31, 2008 – Presentation on "Nitrates and subsurface drainage in southern Iowa" at Crop Advantage Series meeting in Ottumwa, IA (55 attendees).

January 17, 2008 – Presentation on “Nitrates and subsurface drainage in southern Iowa” at Crop Advantage Series meeting in Osceola, IA (40 attendees).

January 8, 2008 – Presentation “Nitrogen management and water quality” to Coldwater-Palmer watershed group in Allison, IA (12 attendees).

January 3, 2008 – Presentation “Considerations for field drainage design” at North Central Crop Clinic in Iowa Falls, IA (50 attendees)

December 19, 2007 – Presentation “Nitrate leaching and subsurface drainage for southern Iowa” at Ag. Chemical Dealer update in Ames, IA (45 attendees).

December 7, 2007 – Presentation “Potential yield impacts of improved drainage” at a meeting of the Iowa Corn Growers Environmental committee in Johnston, IA (15 attendees).

December 7, 2007 – Presentation “Potential yield impacts of improved drainage” at the Iowa Drainage District Association annual meeting in Fort Dodge, IA (55 attendees).

November 28, 2007 – Presentation “Comparison of nitrate-nitrogen in subsurface drainage from continuous corn and corn-soybean rotation” at the Integrated Crop Management Conference in Ames, IA (120 attendees).

August 10, 2007 – Poster presentation “Agricultural drainage research” at the Corn Soybean Initiative Roundtable in Ames, IA.

June 27, 2007 – Presentation “Drainage design for economic and environmental benefits” at Iowa Farm Bureau Conservation and Natural Resource Issues Conference in Des Moines, IA (~30 attendees). [Invited]

March 13, 2007 – Presentation “Controlled drainage – water quality benefits and irrigation potential” at Drainage Workshop in West Bend, IA (20 attendees).

March 13, 2007 – Presentation “Long-term benefits of tiling” at Drainage Workshop in West Bend, IA (20 attendees).

January 24, 2007 – Presentation “Drainage/water quality: Implications of continuous corn” at Crop Advantage Series meeting in Waterloo, IA (~55 attendees).

January 18, 2007 – Presentation “N-application impacts on N-concentration” at Coldwater-Palmer Watershed meeting in Allison, IA (12 attendees).

January 10, 2007 – Presentation “Drainage/water quality: Implications of continuous corn” at Crop Advantage Series meeting in Mason City, IA (~55 attendees).

January 8, 2007 – Presentation “Drainage water management and biofilters in Iowa” at Iowa Land Improvement Contractors Association annual meeting in Des Moines, IA (120 attendees). [Invited by LICA]

December 18, 2006 – Presentation “Pesticide movement in soils” at Agricultural Chemical Update in Denison, IA (40 attendees).

December 8, 2006 – Presentation “Drainage design now and in the future” at Iowa Drainage District Association annual meeting in Fort Dodge, IA (100 attendees).

December 6, 2006 – Presentation “Pesticide movement in soils” at Agricultural Chemical Update in Ames, IA (10 attendees).

November 30, 2006 – Presentation “Economic and environmental considerations for drainage design” at Integrated Crop Management Conference in Ames, IA (225 attendees).

September 7, 2006 – Presentation “Conservation systems and water quality” at Field Day in Hardin County (~45 attendees).

September 6, 2006 – Presentation “Conservation systems and water quality” at Field Day in Plymouth County (~100 attendees).

August 31, 2006 – Presentation “Conservation systems and water quality” at Farm Progress Show.
August 22, 2006 – Presentation “Beef manure and water quality issues” at Manure Management School in Ames, IA (50 attendees).
August 3, 2006 – Presentation “Subsurface drainage bioreactors” at Iowa Land Improvement Contractors Field Day (~65 attendees).
July 12, 2006 – Presentation “Benefits of tiling and drainage water management” at Drainage Field Day at Southeast Iowa Research Farm, CCA Session (50 attendees).
June 19, 2006 – Presentation “Water quality issues in Iowa” to Iowa Pork Industry Center Advisory Group.
March 13-17, 2006 – Presentation “Long-term benefits of tiling” at Iowa Drainage Design Workshops (~200 attendees).
March 13-17, 2006 – Presentation “Controlled drainage: water quality benefits and irrigation potential” at Iowa Drainage Design Workshops (~200 attendees).
March 7, 2006 – Presentation “Conservation systems: manure and drainage water quality” at Agriculture and the Environment Conference in Ames, IA (150 attendees).
March 7, 2006 – Presentation “Subsurface drainage and nitrate-nitrogen leaching from fifteen years in north-central Iowa” at Agriculture and the Environment Conference in Ames, IA (50 attendees).
March 2, 2006 – Presentation “Nitrogen timing effects on drainage water quality” to Iowa Farm Bureau Environmental Advisory Committee [Invited].
February 15, 2006 – Presentation “Drainage design” at Soil and Water Management Clinic in Ames, IA (10 attendees).
February 15, 2006 – Presentation “Drainage water management” at Soil and Water Management Clinic in Ames, IA (10 attendees).
January 24, 2006 – Presentation “Conservation systems: manure and drainage water quality” at Crop Advantage Series meeting in Storm Lake, IA (45 attendees).
January 19, 2006 – Presentation “Conservation systems: manure and drainage water quality” at Crop Advantage Series meeting in Spirit Lake, IA (50 attendees).
January 18, 2006 – Presentation “Agricultural drainage and water research” at Boone, IA weekly ag meeting (26 attendees).
January 13, 2006 – Presentation “Manure and drainage water quality” at North Central Iowa Crop Clinic (25 attendees).
January 12, 2006 – Presentation “Drainage water management” to Boone River Watershed Group (15 attendees).
January 10, 2006 – Presentation “Basic drainage design” at Iowa Land Improvement Contractors Association annual meeting in Des Moines, IA (80 attendees).
January 9, 2006 – Presentation “Drainage water management in Iowa” at Iowa Land Improvement Contractors Association annual meeting in Des Moines, IA (100 attendees).
December 15, 2005 – Presentation “Drainage management and cropping practices” at Iowa Drainage District Association annual meeting in Fort Dodge, IA (75 attendees).
November 30 and December 1, 2005 – Presentation “Conservation systems: effects of manure on drainage water quality” at Integrated Crop Management conference in Ames, IA (220 attendees).
August 24, 2005 – Presentation “Manure effects of water quality” at Manure Management Clinic in Ames, IA (40 attendees).

July 28, 2005 – Presentation "Subsurface drainage design and drainage water management in Iowa" at Ag Insights: Water Management Solutions, meeting sponsored by Hancor in Oelwein, IA (50 attendees).
July 7, 2005 – Presentation "Drainage design for crop production and environmental benefits" at Pro Ag Meeting, Mitchell County Extension, Osage, IA (15 attendees).
January 25, 2005 – Presentation "New tiling research in Iowa" at Crop Advantage Series meeting in Atlantic, Iowa (120 attendees).
January 12, 2005 – Presentation "Modified drainage for improved water quality" at North Central Crop Clinic in Iowa Falls, IA (45 attendees)
January 11, 2005 – Presentation "Tiling research at Iowa State University" at Iowa Land Improvement Contractors of America annual meeting in Des Moines, IA (60 attendees).
January 6, 2005 – Presentation "New tiling research in Iowa" at Crop Advantage Series meeting in Cedar Rapids, Iowa (40 attendees).
January 4, 2005 – Presentation "New tiling research in Iowa and economic considerations" at Crop Advantage Series meeting in Mt. Pleasant, Iowa (25 attendees).
March 1-3, 2005 – Presentation "Wetland design for drainage water treatment" at Minnesota Agricultural Drainage Design Workshop in Mankato, MN (45 attendees).

Extension Presentations (Regional):
October 15-16, 2007 – Project team was involved with presenting information on nitrate removal wetland performance at an IDALS organized meeting with representatives of USDA-FSA, USEPA, state agency, and other NGO personnel from across the cornbelt.
April 4, 2007 – Presentation "Manure application on legumes" at Heartland Animal Manure Management Workshop in Nebraska City, NE (~35 attendees from Iowa, Missouri, Nebraska, Kansas, and EPA) [Invited].
April 4, 2007 – Presentation "ISU long term poultry and swine manure studies on tile drain impacts" at Heartland Animal Manure Management Workshop in Nebraska City, NE (~40 attendees from Iowa, Missouri, Nebraska, Kansas, and EPA) [Invited].
March 8, 2007 –Presentation "Wetland design considerations for drainage water treatment" at Minnesota Agricultural Drainage Design Workshop in Mankato, MN (40 attendees).
March 7, 2007 –Presentation "Intro to conservation drainage design: Shallow and managed drainage systems" at Minnesota Agricultural Drainage Design Workshop in Mankato, MN with Gary Sands(40 attendees).
February 16, 2007 – Webcast presentation "Effects of manure application on drainage water quality" as part of the National Livestock and Poultry Environmental Learning Center webcast series. [Invited – national audience]
November 28, 2006 – Presentation "Drainage Water Management Update from Iowa" at IA-MN Drainage Research Forum in Dows, IA (85 attendees consisting of producers, contractors, and agency representatives from Iowa and Minnesota).
October 16, 2006 – Presentation "Effects of Manure on Drainage Water Quality" to Nebraska Livestock and Environment Issues Committee (~40 participants) [Invited].
March 9, 2006 – Invited presentation "Wetland design for drainage water treatment" at Minnesota Agricultural Drainage Design Workshop in Mankato, MN (50 attendees).
June 7-9, 2005 – Presentation "Subsurface drainage and treatment of drainage water to reduce nitrate-N" at Heartland Water Quality Initiative Nitrogen Workshop in Nebraska City, NE (75 attendees from Iowa, Nebraska, Kansas, Missouri, and USEPA).

June 7-9, 2005 – Presentation “Design of drainage water treatment facilities” at Heartland Water Quality Initiative Nitrogen Workshop in Nebraska City, NE (20 attendees from Iowa, Nebraska, Kansas, Missouri, and USEPA).

January 26-27, 2005 – Presentation “Drainage design and management” at Heartland Water Quality Initiative Nitrogen Roundtable in Nebraska City, NE (30 attendees from Iowa, Nebraska, Kansas, Missouri, and USEPA).

Technical Papers (Peer-reviewed)

Riley, K. D., M. J. Helmers, P A. Lawlor, and R. Singh. Water balance investigation of controlled drainage in non-weighing lysimeters. Submitted June 11, 2008 to: *Applied Engineering in Agriculture* (in review).

Qi, Z. and M.J. Helmers. Soil water dynamics under winter rye cover crop in central Iowa. *Vadose Zone Journal* Accepted February 5, 2009.

Lawlor, P. A., M. J. Helmers, J. L. Baker, S. W. Melvin, and D. W. Lemke. 2008. Nitrogen application rate effects on nitrate-nitrogen concentrations and losses in subsurface drainage. *Trans. ASABE* 51(1): 83-94.

Singh, R., M. J. Helmers, W. G. Crumpton, and D. W. Lemke. 2007. Predicting effects of drainage water management in Iowa’s subsurface drained landscapes. *Agricultural Water Management* 92:162-170.

Singh, R., M. J. Helmers, and Z. Qi. 2006. Calibration and validation of DRAINMOD to design subsurface drainage systems for Iowa’s tile landscapes. *Agricultural Water Management*. 85: 221-232.

Technical Papers, Conference Papers, and Extension Related Publications

Qi, Z., M.J. Helmers, and P. Lawlor. 2008. Effect of different land covers on nitrate-nitrogen leaching and nitrogen uptake in Iowa. ASABE Meeting Paper No. 08-4806. St. Joseph, MI: ASABE. [Oral Presentation – Qi]

Qi. Z. and M. J. Helmers. 2008. Effect of cover crops in reducing nitrate-nitrogen leaching in Iowa. *In:* Proceedings of the 20th Annual Integrated Crop Management Conference (December 10 and 11, Iowa State University, Ames, IA), pp. 283-294. [Oral Presentation - Helmers]

Helmers, M. 2007. Drainage/water quality: Implications of continuous corn. p. 28. In *2007 Proceedings Crop Advantage Series*. AEP 0200f. Iowa State Univ., Ames, IA.

Helmers, M. J. and P. Lawlor. 2007. Comparison of nitrate-nitrogen in subsurface drainage from continuous corn and corn-soybean rotation. In *Proceedings of the 19th Annual Integrated Crop Management Conference* (November 29 and 30, 2007, Iowa State University, Ames, IA), pp. 265-277. [Oral Presentation]

Helmers, M. J. and R. Singh. 2006. Economic and environmental considerations for drainage design. In *Proceedings of the 18th Annual Integrated Crop Management Conference* (November 29 and 30, 2006, Iowa State University, Ames, IA), pp. 239-244. [Oral Presentation]

Singh, R. and M. J. Helmers. 2006. Subsurface drainage and its management in the upper Midwest tile landscape. In *Proceedings of the EWRI Congress, ASCE* [Oral Presentation].

Lawlor, P. A., M. J. Helmers, J. L. Baker, S. W. Melvin, and D. W. Lemke. 2005. Nitrogen application rate effects on corn yield and nitrate-nitrogen concentration and loss in subsurface drainage. ASAE Meeting Paper No. 05-2025. St. Joseph, MI: ASAE.

M. J. Helmers, P. A. Lawlor, J. L. Baker, S. W. Melvin, and D. W. Lemke. 2005. Temporal subsurface flow patterns from fifteen years in north-central Iowa. ASAE Meeting Paper No. 05-2234. St. Joseph, MI: ASAE.

Helmers, M. J. and P. A. Lawlor. 2005. Conservation systems: Effects of manure application on drainage water quality. In *Proceedings of the 17th Annual Integrated Crop Management Conference* (November 30 and December 1, 2005, Iowa State University, Ames, IA), pp. 177-188.

Technical Abstracts

Qi, Z. and M. J. Helmers. 2007. Soil moisture and subsurface drainage with winter rye cover crop in Iowa. *In:* ASABE International Meeting. June 17-20, 2007, Minneapolis, MN.

Lemke, D.W., R. L. Cooney, S.L. Richmond, W.G. Crumpton, and M. J. Helmers. 2006. A new vision for federal policy to facilitate restoration and development of wetlands as off-field nitrogen sinks for cropped landscapes. *In:* ASA-CSSA-SSSA Annual Meeting Abstracts. Nov. 12-16, 2006, Indianapolis, IN.

Qi, Z., M. Helmers, and R. Singh. 2006. Evaluating a drainage model using soil hydraulic parameters derived from various methods. ASAE Meeting Paper No. 062318. St. Joseph, Mich.: ASAE.

Singh, R. and M. J. Helmers. 2006. Shallow and controlled drainage systems in Iowa's tile landscapes. *In:* ASA-CSSA-SSSA Annual Meeting Abstracts. Nov. 12-16, 2006, Indianapolis, IN.

Poster Presentations at Extension Related Meetings

June 28, 2006 - Poster Presentation "Water and nutrient management: In-field strategies" Iowa Farm Bureau Ag. And Environment Conference (~65 attendees)

Helmers, M. J., P. A. Lawlor, J. L. Baker, S. W. Melvin, W. Crumpton, D. W. Lemke. 2005. Temporal subsurface flow patterns from fifteen years in north-central Iowa. Agriculture and the Environment Conference (March 8-9, 2005, Iowa State University, Ames, IA).

P. A. Lawlor, M. J. Helmers, J. L. Baker, S. W. Melvin, W. Crumpton, D. W. Lemke. 2005. Nitrogen application rate effects on yield, nitrate-nitrogen concentration and loss in subsurface drainage. Agriculture and the Environment Conference (March 8-9, 2005, Iowa State University, Ames, IA).

Planned Manuscripts to be Submitted in 2009

Lawlor, P. A., M. J. Helmers, J. L. Baker, and S. W. Melvin. Nitrogen source and timing effects on yields and nitrate-nitrogen concentrations in subsurface drainage from a corn-soybean rotation. To be submitted to *Trans ASABE*. [Draft prepared]

Helmers, M.J., P. Lawlor, J. L. Baker, and S. W. Melvin. Nitrate-nitrogen in subsurface driange as affected by nitrogen application rate to continuous corn and a corn-soybean rotation. To be submitted to *Agriculture, Ecosystems and Environment*. [Draft prepared]